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CONTENTS

Anatomy. — *The fissuration on the frontal lobe of Sinanthropus pekinensis Black, compared with the fissuration in Neanderthalmen.* By C. U. ARIËNS KAPPERS.

(Communicated at the meeting of November 25, 1933.)

Although Dr. DAVIDSON BLACK already gave us a description of the endocranial cast of the adolescent Sinanthropus pekinensis [1]), he did not enter into the details of the fissures especially instructive on the right frontal lobe of the cast. Nor did DUBOIS [2]), who recently gave a general discussion of this cast confirming BLACKs conclusion about its human, especially Neanderthaloid features. In the following pages I shall try to identify the fissures and compare them with those on Neanderthalmen casts, especially the endocranial cast of the Rhodesian skull.

Before doing so I want to point out some of its general features as they appear by the encephalic (and endocranial) indices also used in the description of other prehistoric casts and recent brains (see table) [3]).

Endocr. meas. and ind.	Pithec.	Sin.	Rhodes.	La Chap.	Aver. Predm. III, IV . X
length right hem.	15.45	15.99	17.35	18.55	—
length left hem.	15.43	15.92	17.20	18.15	—
total breadth	12.62	12.30	13.68	14.60	—
l. br. ind. right	81.1	76.9	78.8	78 8	—
l. br. ind. left	81.1	77.07	79.5	80.40	—
aver. l. br. ind.	**81.1**	**76.95**	**79.15**	**79.60**	**77.1**
gen. height ind.	0.400	0.453	0.478	0.477	0.516
occ. height ind.	0.938	1.086	1.20	0.96	1.455
temp. depth ind.	?	0.173[5])	0.130	0.153	0.140
temp. length ind.	0.742[4])	0.732[5])	0.762	0 763	0.769

[1]) A. DAVIDSON BLACK, On the endocranial cast of the adolescent Sinanthropus, Proc. of the Roy. Soc. London, Ser. B, Vol. **112**, N⁰. B, 776, Jan. 2d. 1933. The age of this individual is estimated by BLACK to be 15—16 years.

[2]) E. DUBOIS, The shape and size of the brain in Sinanthropus and Pithecanthropus, Proc. Kon. Akad. v. Wetensch. Amsterdam, Vol. **36**, N⁰. 4, 1933.

[3]) I use this occasion at the same time to give more accurate figures concerning the Rhodesian and La Chapelle casts.

[4]) The temporal length has been measured in these casts from the insular perpendicular i.e. from the perpendicular passing along the frontal pole of the temp. lobe. The larger temporal length in Pithecanthropus is chiefly due to the relatively smaller length of the frontal lobe.

[5]) Only the left temporal lobe of Sinanthropus being complete, these indices only refer to the left hemisphere. The general and occipital height indices mentioned are the mean of both sides.

Comparing the indices in the adjoining table, it appears that the Sinanthropus cast differs from the Pithecanthropus cast in the following points:

1⁰. By its length breadth index (Sin. 76.95; Pith. 81.1); 2⁰. By its greater general height index (Sin. 0.453; Pith. 0.400); 3⁰. By its smaller temporal length index (Sin. 0.732; Pith. 0.742) and 4⁰. By its larger occipital height index (Sin. 1.086; Pith. 0.938).

Comparing these indices with those of the two Neanderthal casts, mentioned in my list, it appears that also their length breadth indices are below 80, but that these casts differ from the Sinanthropus cast in the following points: 1⁰. By a somewhat higher length-breadth index [1]). 2⁰. By their greater average general height index (Sin. 0.453; average Neand. 0.477). 3⁰. By their smaller temporal depth index (Sin. 0.173; av. Neand. 0.142). 4⁰. By their larger temporal length index (Sin. 0.732 av. Neand. 0.762).

Considering the bearing of these differences we may say that, as pointed out by BLACK and DUBOIS, by its length breadth index Sinanthropus comes in the same group as Neanderthal men. The same is shown by its general height index.

The greater general height index of Sinanthropus compared to Pithecanthropus is of the more importance as very often in brachencephalic individuals (as Pithecanthropus is) the height of the brain tends to increase. That notwithstanding its smaller length-breadth index the height-index in Sinanthropus is larger, is the more expressive of its human character.

The same was pointed out in a more general way by DUBOIS, who called the attention to the humanlike *parietal vertex* of this cast in contrary to the flat dorsal surface of the Pithecanthropus cast. As already Sir ARTHUR KEITH [1]) (l.c., p. 388) stated "the rise of the parietal area of the cranial vault is a human character".

Also by its occipital index (the parietal perpendicular divided by its distance from the occipital pole) the Sinanthropus brain comes in the group of the Neanderthaloid brains (Sin. 1, 086, average of the two Neanderthal casts 1.08).

The lesser temporal length index in Sinanthropus compared to Pithecanthropus is an expression of the greater relative development of its frontal lobe as measured from the insular perpendicular. The lesser size of the frontal lobe in Pithecanthropus agrees with the difference in fissuration — the fissuration in the latter being chimpanzoid [3]) in its general character,

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[1]) I may, however, add that the La Quina cast has a smaller encephalic index than Sinanthropus (73, 6).

[2]) A. KEITH, The antiquity of man, Vol. II, seventh edition, WILLIAMS and NORGATE, London 1929.

[3]) C. U. ARIËNS KAPPERS, The fissures on the frontal lobe of Pithecanthropus erectus DUBOIS etc. These Proceedings, Vol. 32, 1929, p. 182. See also A. KEITH, Report on the Galilee skull. Publ. of the British school of Archeology in Jerusalem, 1927.

whereas the fissuration of Sinanthropus, as will be shown below, is distinctly human.

The increase of the temporal length index in the Neanderthalmen is due to an elongation of the tempero-occipital region, probably by the increase of the parieto-occipital association fields, so characteristic of the human brain in comparison with apes. This difference is also reflected in the next point in which Sinanthropus differs from Neanderthal casts: its deeper temporal lobe [1]) the relative depth of which exceeds that of all the Neanderthal casts I measured. The same holds good for the rostrum orbitale (fig. 3 and 5) in Sinanthropus (the "bec encéphalique" of M. BOULE [2])).

Looking at the average indices as found in the three Predmost casts we see that the same line of evolution continues in the upper paleolithic men as not only appears from the increase of the general and occipital height indices, but also from the decrease of the temporal depth and increase of the temporal length index, and furthermore by a less outstanding rostrum orbitale in upper paleolithic endocranial casts.

That the relations in Sinanthropus, notwithstanding the small capacity of its cast [3]) (between 900 and 964 cc. according to BLACK; 198 cc. according to DUBOIS), are distinctly human also appears from the fissuration on the left orbital surface (the only one present) and especially from the fissures on the convexity of the right frontal lobe, a drawing of which was made by our artist Mr. CHR. VLASSOPOULOS, in the same way as he drew the other casts I hitherto described i.e. with tangential light on each fissure separately, this being the only way to bring out clearly the surface relief.

Of the orbital surface a photograph was taken (fig. 1). I shall compare the orbital sulci of the left hemisphere (those on the right being added symmetrically) with those of the Rhodesian cast, this being the only Neanderthaloid cast at my disposal (and in my knowledge) showing the orbital sulci distinctly on both sides. Comparing fig. 1 and 2 it is at once striking that the orbital sulci in both casts are nearly identical. In Sinanthropus only the sulcus olfactorius, the lateral limiting sulcus of the gyrus rectus, fails, owing to a gap in the skull.

In both casts an internal and external orbital sulcus may be distinguished. On the left orbital surface of the Rhodesian the internal sulcus consists of two parts, running partly parallel.

The internal orbital in Sinanthropus is very short, resembling the sagittal limb of the loose caudal part of the internal orbital on the same side in the Rhodesian. The external orbital is very similar in both.

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1) A large temporal depth index, i.e. a short but deep temporal lobe is a primitive feature.

2) M. BOULE, l'Homme fossile de la Chapelle aux Saints. Annales de Paléontologie 1911. In anthropoid apes the rostrum orbitale is very pronounced.

3) It is evident that as long as the bodyheight of this individual cannot be estimated with any certainty we can say nothing about his cephalisationcoëfficient. If the body is small, this coëfficient might be human, even with this skull capacity.

Fig. 1

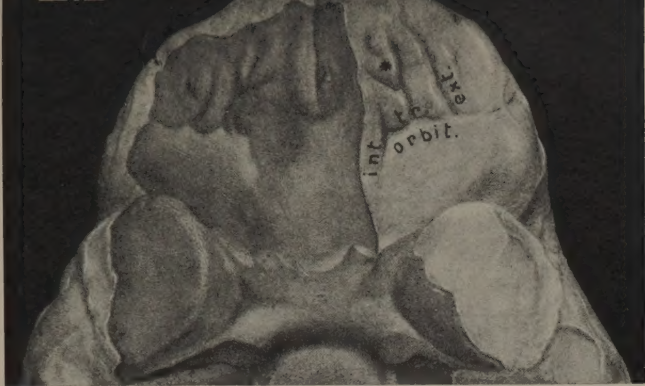

Fig. 2

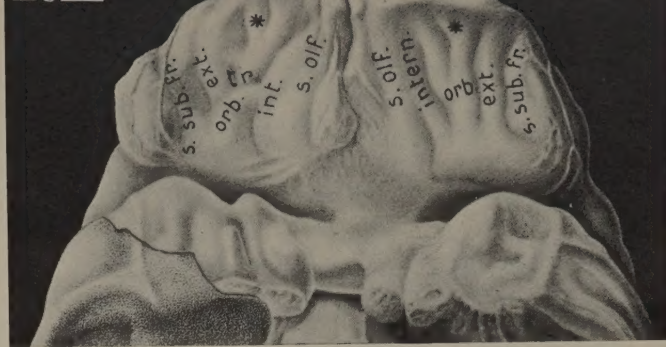

Fig. 3

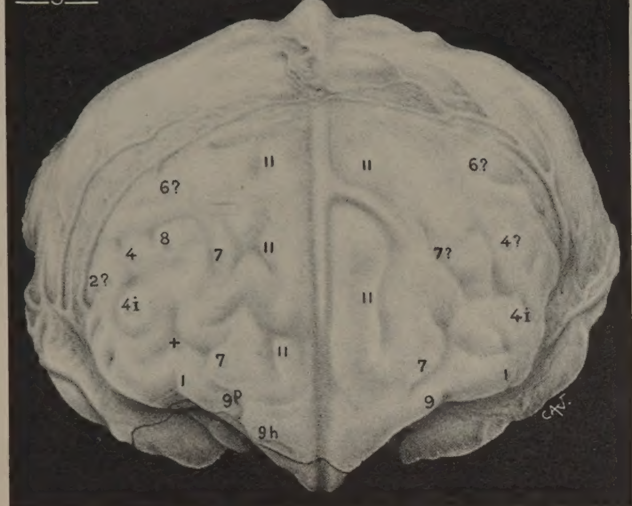

Fig. 2a

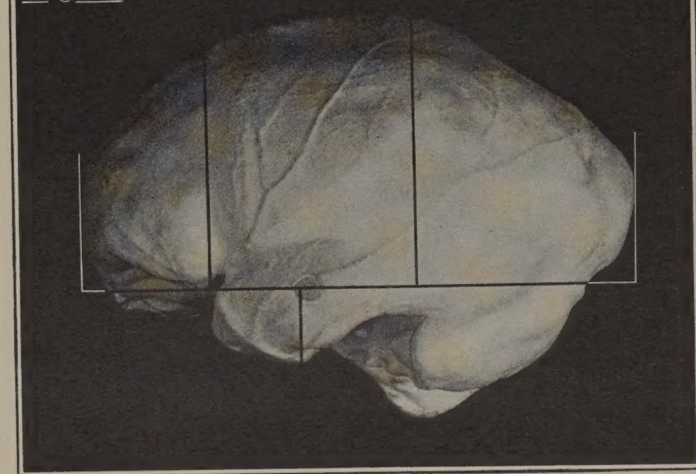

Fig. 1. Orbital surface and fig. 3 frontal aspect of the Sinanthropus cast. Fig. 2. Orbital surface of the Rhodesian cast. In fig. 2 and 3 the fissures are drawn with tangential light; fig. 1 is a photograph. Fig. 2a. Rhodesian cast, left hemisphere, lateral aspect,

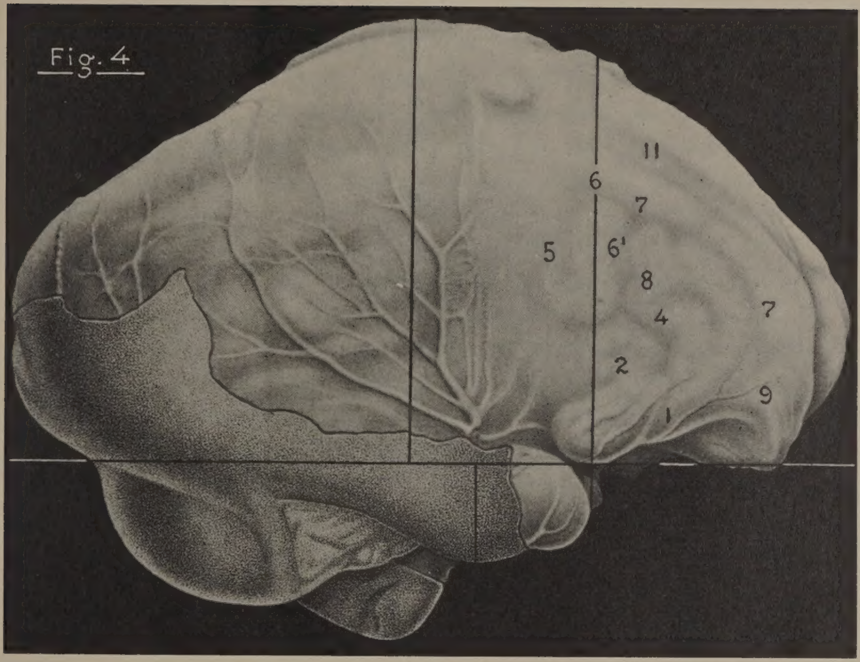

Fig. 4. Right hemisphere of the Rhodesian cast (not exactly lateral, showing the interhemispherial fissure in front).

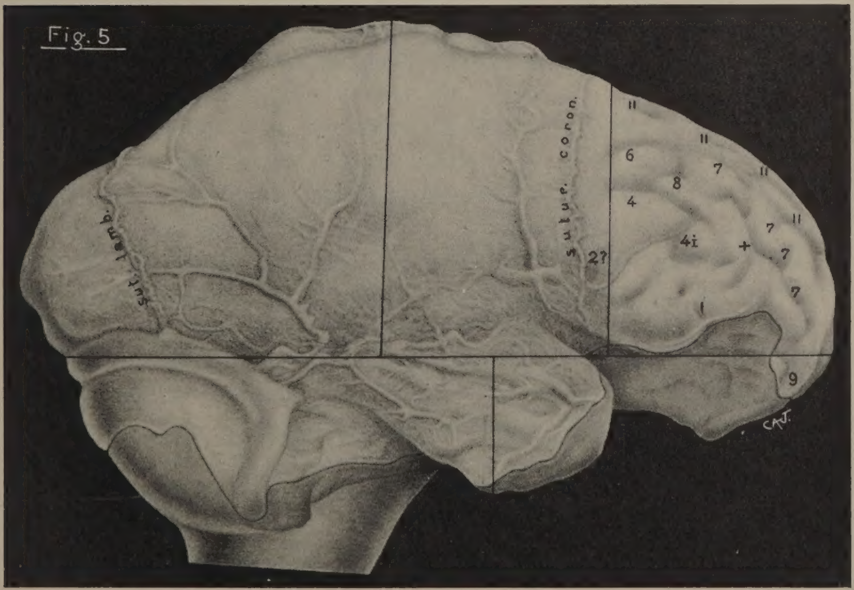

Fig. 5. Right hemisphere of the Sinanthropus cast (exactly lateral). In both casts the fissures are drawn with tangential light (see text p. 804).

Frontally, in between these sulci some additional small grooves (at *) occur which in the Rhodesian on the right hemisphere are independant from each other, but on the left form one bifurcating sulcus [1]) as they do in Sinanthropus. These intermedio-frontal orbital sulci are also frequently seen in recent men. A transverse orbital fails on the left hemisphere of the Rhodesian but is present on the right hemisphere at about the same spot as in Sinanthropus on the left hemisphere.

If in both casts we trace a line from the most frontal point of the temporal lobe to the most frontal point of the brain, it appears that in both the transverse orbital lies on about the middle of this line.

In Sinanthropus, however, the transverse orbital extends beyond the external orbital, reaching in front of the operculum orbitale.

This operculum orbitale is more or less delimited also caudally by a groove. In the Rhodesian the operculum is better delimited by a distinct continuous sulcus, the subfrontal (N⁰. 1 of my enumeration).

Here the operculum orbitale also extends somewhat more frontally than in Sinanthropus, being more pronounced in the former. In both casts, however, the whole arrangement on the orbital surface is evidently human.

Looking at the frontal aspect of the cast we are struck by the large rostrum orbitale (fig. 3) which is even more expressed than in the Neanderthalmen of La Chapelle and Saints, where its large size was emphasized by BOULE (l.c.). This is probably due to the relative smallness of the brain in comparison to the orbits. The large size of the rostrum also appears from its extension underneath the lateral horizontal (c.f. fig. 2*a* and fig. 5).

Proceeding to the convexity of the brain I shall only compare the right frontal lobes as here the fissures are best indicated in both specimens. For this I refer to figs 4 and 5 in which also the (parietal and) insular perpendicular are drawn to facilitate comparison [2]).

In Sinanthropus (fig. 5) the insular perpendicular passes through the caudal part of fissure 4 (inferior frontal).

This fissure continues and finishes probably behind the coronal suture, as it does in recent men (HORSLEY [3])), cf. Plate VII, fig. 11 representing a boy of the same age — 15 years — as given to this Sinanthropus). In the Rhodesian the same relation to the insular perpendicular is observed with fissure 4, that clearly extends behind this perpendicular.

In both casts fissure 4 turns downward frontally (fig. 5 : $4i$ = r. inferior) and the relation of this curve to the frontal end of the operc. orbitale indicated by fiss. 1 is similar in both casts. Furthermore in both casts there is a dimple 8 over de middle of 4, to which I never gave a name but which frequently occurs, also in recent human brains, and even in Anthropoids

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1) Not well visible in fig. 2.

2) In comparing fig. 4 with fig. 5 we should keep in mind that fig. 4 is not exactly lateral.

3) V. HORSLEY, On the topographical relations of the cranium and the surface of the cerebrum. Cunningham memoirs N⁰. VII, published by the Royal Irish Academy 1892

(Chimpanzees) and in Pithecanthropus. This dimple may (fig. 4) or may not (fig. 5) be connected with 4 [1]).

While thus the course of 4 is about the same in both casts, the relative size of the inferior frontal convolution of which it forms the dorsal border is very different in both brains. The inferior frontal convolution, on which in both casts there may be only one anterior Sylvian branch (2), is large in Sinanthropus (cf. also BLACK), much larger than in Pithecanthropus. It even seems larger than in the Rhodesian. This, however, is not due to its absolute greater size in Sinanthropus but to an increase of the midfrontal region in the Rhodesian.

That this is true appears if we compare the midfrontal fiss. 7.

As I have frequently pointed out [2]) fiss. 7 (the horizontal limb of the anthropoid arcuate fissure) is much more important in the phylogeny of the frontal lobe and also in recent human brains than is usually realized. Its phylogenetic importance surpasses by far that of the superior frontal (11).

The typical characteristic of fiss. 7 is its being made up of arches beginning with its caudal relation to 6, a short curve that frequently connects 7 with 5 (the inferior precentral) and which was called by EBERSTALLER [3]) and CUNNINGHAM [4]), the horizontal limb of the inferior praecentral. This figure 6 is indicated in the Rhodesian as well as in Sinanthropus.

Another feature of 7 is given by its ventral offshoots that may even connect with dimple 8 (as is indicated by 6′ in the Rhodesian) as well as with fissure 4. These ventral offshoots may introduce a splitting up of the midfrontal fissure in various independant arches.

Its most typical characteristic, however, is that it actually or virtually continues in fiss. 9, the perpendicular branch of WERNICKE's frontomarginal. Especially in recent men this is a good point de repère as the frontal part of 7 is more constant than its caudal part which in recent races is so frequently broken up in various arches or even in perpendicular fissurets owing apparently to evolutionary processes in this region [4]).

Fissure 7, well indicated in the Rhodesian and in Sinanthropus, separates the mid-frontal region in an upper and lower part. Especially the *foot* of the midfrontal region — between 6 and 4 — tends to increase in further evolution. QUANJER [6]) and Dr. VAN BORK—FELTKAMP [7]) showed

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[1]) It may be connected also with 7. This connection is made by fiss. 6′ in the Rhodesian (fig. 4), and also indicated in Sinanthropus.

[2]) Cf. also The DAVID FERRIER lecture on some correlations between brain and skull. Transact. of the Roy. Soc. London, Ser. B., Vol. 221, 1932.

[3]) O. EBERSTALLER, Das Stirnhirn, Graz, 1890.

[4]) J. D. CUNNINGHAM, Surface anatomy of the human hemispheres. Cunningham memoirs N^{0}. VII published by the Royal Irish Academy, 1892.

[5]) This is the reason that the midfrontal as an entitety is so often neglected in human anatomy, or that only the frontal end is recognised.

[6]) A. A. QUANJER, Zur Morphologie der Insula Reilii und ihre Beziehungen zu den Opercula. Petrus Camper, Deel 2, 1902.

[7]) Dr. A. VAN BORK—FELTKAMP, Uitkomsten van een onderzoek van een zestigtal hersenen van Chineezen. Dissertatie, Amsterdam, 1930.

that it even sometimes operculates the inferior frontal sulcus. This is probably connected with the localisation of the centre of conjugate deviation in this foot (i.e. where it touches the inferior precentral), the importance of which for the evolution of the frontal lobe, was already realized by FERRIER [1]). If we now compare the height of the midfrontal foot with the height of the inferior frontal convolution in Sinanthropus and in the Rhodesian it appears that the midfrontal foot is larger in the latter.

I may add to this that the further development of the lower midfrontal region in recent brains shows its influence also in a dorsal direction and thus may cause fissure 7 to be pressed against the superior frontal fissure (11) and even become partly incorporated in it [2]).

In Sinanthropus a small groove (+) occurs, connected with the frontal end of 7. In the Rhodesian an analogous fissure (not labelled) is seen, but not connecting with 7.

About the superior frontal (11) — much less important than usually stated in anatomy books — I can be brief.

This fissure, running parallel to the mesial edge of the hemisphere, is clearly indicated in Sinanthropus but hardly in the Rhodesian.

It has the same relative location and extension in Sinanthropus as it usually has in recent man. It consists of two parts (fig. 3) and where it is broken it has a transverse connection with 7, as often occurs in man.

The left frontal lobe of Sinanthropus is much less typical than the right. The frontal end of 11 is clearly indicated, similarly the frontal end of fissure 7 and its connection with 9 (fig. 3).

There seems to be a connection of the frontal part of 7 with a part of fiss. 4, reminding a relation also indicated on the left hemisphere of the La Chapelle and La Quina casts [3]). From the point where this connection enters the small remnant of 4 a large inferior branch (4*i*) extends ending on the operculum orbitale in a triradiate fissure of EBERSTALLER (my N⁰. 3, not visible in fig. 3). No other grooves could be identified with some certainty on the left frontal lobe.

Although a lunate sulcus of ELLIOT SMITH cannot be identified with certainty in Sinanthropus pekinensis, a mesial impression on the left occipital lobe — at some distance behind the lambda suture i.e. in a position where it also frequently occurs in recent men, may be caused by such a sulcus, or rather by a sulc. polaris superior, described by ELLIOT

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[1]) D. FERRIER, The functions of the brain (2d. edition), London 1877, 1887).

[2]) The alternating of the course of parts of 7 in 11 has been masterly described by SERGI (cf. his papers: Sui variazioni dei solchi del lobo frontale negli Hominidae Rivista di Anthropologa, Vol. 18, fasc. I—II, 1913, and Ueber die Morphologie und Symmetrie des Lobus frontalis beim Menschen. Zeitschr. f. Morphologié und Anthropologie, Bnd. **17**, 1926.

[3]) Cf. ARIËNS KAPPERS, Further communications on the fissures of the frontal lobes in Neanderthalmen. Proceed. of the Kon. Akad. v. Wetensch. Amsterdam, Vol. 32, 1929, p. 196. See also: The evolution of the nervous system in Invertebrates, Vertebrates and Man. Erven F. BOHN. Haarlem, 1929.

SMITH[1]) as a limiting sulcus of the dorso-mesial region of the area striata. This sulcus may anastomose with the lunatus (cf. ELLIOT SMITH, l.c., fig. 5) that usually lies more laterally. As also in Sinanthropus lateral of the dorso-mesial indentation there is another, very small, but distinct impression on the same distance from the lambda suture the latter impression might be an indication of the lunate itself, as also stated by BLACK.

On the right side no trace of it is seen[2]). Although in the Rhodesian cast there is no indication of a lunate sulcus, it also occurs in the Neanderthalman from Düsseldorf, on the left occipital lobe only (l.c.).

This agrees with the statement first made by ELLIOT SMITH and frequently confirmed that in recent man this sulcus occurs more often on the left than on the right in its typical human shape.

Resuming we may say that the encephalic indices and the fissuration of the frontal lobes of the Sinanthropus cast confirm BLACK's statement that we have to do with a humanlike Neanderthaloid individual, as was also confirmed by E. DUBOIS. We may, however, add that some of the indices, the very large rostrum and the relation in the foot of the midfrontal convolutions, together with the small capacity of the skull — even for an adolescent — may indicate a more primitive condition than in other Neanderthaloids. The study of the endocranial cast and other morphological features of more and especially of adult specimens is, however, necessary before making a definite conclusion in this respect.

ARTERIES.

In addition to the branches of the dural art. meningea media (so well described by BLACK), markings of some midcerebral arteries seem to occur on the right frontal lobe. One, running underneath the operculum, reaches the convexity at the subfrontal fissure (1) extending to the junction of 7 and 9 (see fig. 5). Its course agrees approximately with the external orbital artery of CUNNINGHAM's textbook (3d ed. fig. 626), the inferior orbito-frontal artery of BOUMAN and LEY. SHELLSHEAR described its anthropoid homologue (reaching the convexity at the fronto-orbital sulcus) as fronto-marginal artery (for his field 19). The second, running obliquely from 2 ? to 4i (fig. 5), is a branch of CUNNINGHAM's external frontal, BOUMAN and LEY's external orbito-frontal (artère de la troisième convolution frontale of POIRIER and SHARPY). This artery has various branches (that pass also beyond the inferior frontal sulcus). Our branch resembles SHELLSHEAR's middle branch (vascularising his field 17) or ascending branch (also drawn by DURET) of K. H. BOUMAN and LEY who gave us the average course of these branches in 25 human brains.

These relations agree entirely with the diagnosis of the sulcal pattern on this lobe.

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1) G. ELLIOT SMITH, The variations in the folding of the visual cortex in man. MOTT, Memorial Volume, LEWIS and Co., London, 1929.

2) On the right side a much more caudal impression, about 1 c.m. over the transverse sinus may be caused by a lateral or external calcarine (BLACK), better called occipitalis horizontalis (ZIEHEN), a limb of my ypsiliform fissure. See also KUHLENBECK, Bemerkungen zur Morphologie des Occipitallappens des menschlichen Gehirns, Anat. Anzeiger. Bnd. 65, 1928.

Physics. — *Isothermals of helium at temperatures of* 0, 20 *and* 100° C., *and pressures from* 5,5 *to* 16,5 *atmospheres.* By W. H. KEESOM and J. J. M. VAN SANTEN. (Communication No. 227*b* from the KAMERLINGH ONNES Laboratory at Leiden).

(Communicated at the meeting of September 30, 1933.)

Summary. For the sake of thermometry, especially for a more accurate ascertaining of the position of the ice point on the KELVIN-scale, it was resolved some years ago that very careful redeterminations should be made, of the fundamental pressure coefficient of helium on the one hand, of the isothermals of helium at 0° and 100° C. on the other hand. This paper contains the results of the last mentioned investigation. They are:

$$B_{0^\circ C.} = 0.502^8 \times 10^{-3},\ B_{20^\circ C.} = 0.498^9 \times 10^{-3},\ B_{100^\circ C.} = 0.481^4 \times 10^{-3}.$$

The value $B_{100^\circ C.} - B_{0^\circ C.} = -0.021^4 \times 10^{-3}$ is estimated to have a mean error $\pm 0.005 \times 10^{-3}$.

§ 1. *Introduction.* The position of the ice-point (0° C.) on the KELVIN-scale can be derived from measurements with the gasthermometer of the pressure coefficient between 0° and 100° C. (the fundamental temperature interval), and from measurements of the compressibility of the gas used at the temperatures mentioned, *i.e.* of measurements of isothermals. As for helium the difference between the fundamental pressure coefficient $\alpha_{n\,He}$ and the fundamental temperature coefficient α_A is smallest, helium is mostly indicated for investigations on that fundamental constant of thermometry. So it was decided some years ago that for a more accurate determination of the position of the ice point on the KELVIN-scale very careful redeterminations should be made, of the fundamental pressure coefficient of helium on the one hand, of the isothermals on the other hand. The investigation on the fundamental pressure coefficient of helium is still going on. Preliminary results were published [1]). The results of the measurements on the isothermals are given in this paper.

§ 2. The fundamental pressure coefficient is by definition:

$$\alpha_{n\,He} = \frac{p_{100^\circ C} - p_{0^\circ C.}}{p_{0^\circ C.} \cdot 100}, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

$p_{0^\circ C.}$, the icepoint pressure of the gasthermometer, being $100/76 \times$ the normal atmosphere [2]).

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[1]) W. H. KEESOM and Miss H. VAN DER HORST. These Proceedings **30**, 970, 1927, Comm. Leiden N⁰. 188*a*; W. H. KEESOM, A. BIJL and Miss H. VAN DER HORST. These Proceedings **34**, 1223, 1931, Comm. Leiden N⁰. 217*a*, § 3.

[2]) At Leiden 75.9529 cm mercury, cf. Comm. Leiden Suppl. N⁰. 51*a*, p. 11, note 1.

With sufficient accuracy the fundamental temperature coefficient α_A is derived from it by

$$\alpha_A = \alpha_{n\,He} - (1 + 100\,\alpha_A)\,\frac{100}{76}\,.\,\frac{B_{100^\circ\,C.} - B_{0^\circ\,C.}}{100} \quad . \quad . \quad . \quad (2)$$

$B_{0^\circ\,C.}$ and $B_{100^\circ\,C.}$ are the second virial coefficients of KAMERLINGH ONNES' equation of state in the form:

$$p\,v_A = A_A\left(1 + \frac{B}{v_A} + \frac{C}{v_A^2} \cdots\right). \quad . \quad . \quad . \quad . \quad . \quad (3a)$$

The B's are related with the B_A's of the equation

$$p\,v_A = A_A + B_A\,d_A + C_A\,d_A^2 \ldots, \; d_A = v_A^{-1}, \quad . \quad . \quad . \quad . \quad (3b)$$

by $B = B_A/A_A$.

In these equations p is measured in normal atmospheres, v_A is the volume in terms of the normal volume (0° C., 1 atm.).

For determining B it is most advisable to measure isothermals in that range of densities in which on the one hand C does not have an appreciable influence, and on the other hand the term with B is large enough to allow a sufficiently accurate calculation of B [1]). We made measurements in the range of d_A from 4,5 to 12,5.

In this range the term $C_A\,d_A^2$ has a maximum value of about 0,00002 [2]) and can be neglected, so that instead of equations (3) we may write

$$p\,v_A = A_A\left(1 + \frac{B}{v_A}\right), \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4a)$$

$$p\,v_A = A_A + B_A\,d_A \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4b)$$

§ 3. *The experiments.* For the method and the apparatus we refer to previous publications [3]). A report on some improvements made in the course of this investigation was given by one of us elsewhere [4]).

The helium, obtained by evaporation of liquid helium and tested spectroscopically, was contained in a bulb of Jena thermometer glass 2954 III, capacity 40 cm³, connected through a capillary with a cylin-

[1]) Cf. G. P. NIJHOFF and W. H. KEESOM. These Proceedings **28**, 963, 1925. Comm. Leiden N⁰. 179*b*, § 1.

[2]) Calculated from $C_{A\,0^\circ\,C.} = 0{,}12 \,.\, 10^{-6}$, $C_{A\,100^\circ\,C.} = 0{,}16 \,.\, 10^{-6}$. H. KAMERLINGH ONNES. Comm. N⁰. 102*a*. If we should use the german values of C_A, the maximum value of $C_A\,d_A^2$ would be 0,00004. The value of our B's, table IV, must then be diminished with $0{,}0020 \,.\, 10^{-3}$, $B_{100^\circ\,C.} - B_{0^\circ\,C.}$ remains unchanged.

[3]) H. KAMERLINGH ONNES and H. H. FRANCIS HYNDMAN. These Proc. **3**, 621, 1901, Comm. N⁰. 69; J. C. SCHALKWIJK, These Proc. **4**, 23, 1902, Comm. N⁰. 70; H. KAMERLINGH ONNES and C. BRAAK. These Proc. **9**, 754, 1907, Comm. N⁰. 97*a*; H. A. KUYPERS and H. KAMERLINGH ONNES. Arch. Néerl. (IIIA) **6**, 277, 1923, Comm. N⁰. 165*a*; G. P. NIJHOFF and W. H. KEESOM. These Proc. **31**, 404, 1928, Comm. N⁰. 188*b*.

[4]) J. J. M. VAN SANTEN. Wis- en Nat. Tijdschr. **6**, 59, 1932. Comm. Leiden N⁰. 227*a*.

drical glass tube, into which mercury could be pressed, and which was kept at 20° C. The quantity of gas in the bulb was calculated by subtracting from the total quantity the quantity of gas contained in the cylindrical tube (the stem) and the connection. For this purpose the isothermal of 20° C. was determined.

The total quantity was determined by measuring the normal volume. The pressure was measured with a closed manometer, which was compared with the absolute manometer.

0° C. was realised by means of melting ice in equilibrium with air-saturated distilled water, 100° C by means of steam from distilled water, a correction being applied for the deviation of the pressure from the normal atmosphere. For this purpose a new steam point apparatus was built after the design previously described [1]) with some slight improvements.

§ 4. *Volume of mercury menisci.* A serious difficulty was caused by the volume of the mercury meniscus in the piezometer stem, whose average radius was 0.587 cm. Mercury menisci volumes for tubes of about this dimension have been measured by PALACIOS [2]) only. For the average height of our menisci, 0.140 cm, we take from his results $v = 98.0$ mm^3.

For larger radii SCHEEL and HEUSE [3]) have measured menisci volumes. Their results are systematically about 11 mm^3 smaller than PALACIOS' values for those radii. By extrapolating SCHEEL and HEUSE's values one should expect for $r = 0.587$ a volume, 8.5 mm^3 smaller than PALACIOS' number.

In view of this difference and the high importance the exact knowledge of the menisci volumes has for different researches of high accuracy, in this laboratory an elaborate investigation has been taken in hand in which an X-ray shadowgraph of the meniscus is measured. For $r = 0.587$ cm the measurements have been completed: for $h = 0.140$ cm a value of v was found 5.1 mm^3 smaller than PALACIOS' value [4]).

We checked this result by another method. A tube with radius 0.587 cm was connected with an accurately calibrated capillary and filled with very pure mercury. By cautiously changing the pressure above the mercury in the capillary the height of the meniscus in the other tube could be changed, the rim of the meniscus remaining unchanged. So we could measure the differences in volume of menisci from $h = 0.050$ to $h = 0.170$ cm. As an average from 12 series of measurements we found those

[1]) W. H. KEESOM and Miss H. VAN DER HORST. These Proc. **30**, 970, 1927. Comm. N⁰. 188*a*, fig. 1.

[2]) J. PALACIOS. Ann. Soc. Esp. de Fis. y Quim. **17**, 275, 1919; Phys. Zs. **24**, 151, 1923.

[3]) K. SCHEEL and W. HEUSE. Ann. d. Phys. (4) **33**, 295, 1910.

[4]) We gladly record our thanks to Miss H. VAN DER HORST, phil. nat. doct^a and Mr. K. W. TACONIS, phil. nat. cand., for their important help in providing us with this number.

differences 6.6 mm^3 smaller than PALACIOS. By extrapolating to $h=0$ a difference with PALACIOS of 7.6 cm^3 would follow. In taking a weighted mean between this result and that furnished by the *X*-ray method, we assume 6.2 mm^3, so that for $r=0.587$ and $h=0.140$ cm, the meniscus volume is accepted to be 91.8 ± 1.2 mm^3.

As the heights of the different menisci were nearly the same, we applied for all of them the same correction to PALACIOS' values.

§ 5. *The accuracy* of the pv_A's is about 1 : 10000. This gives a mean error of about $0{,}010 \,.\, 10^3$ in the values of B. This resulting error is principally dependent on small accidental errors in the volume and pressure calibrations.

Errors in the temperatures 0° and 100° C., or in the thermal expansion coefficient of glass [1]) are too small to have an appreciable influence on the result. As still remaining errors in the estimation of the volume of the mercury menisci (§ 4) partly cancel one another, the resulting value of $B_{100^\circ C.} - B_{0^\circ C.}$ is more accurate than $0{,}010 \,.\, 10^{-3}$, mentioned above. The estimated mean error in $B_{100^\circ C.} - B_{0^\circ C.}$ is $0{,}005 \,.\, 10^{-3}$, corresponding with an error of 0,005 degree in the fundamental interval, of $0{,}9 \times 10^{-7}$ in α_A, or of 0,007 in $T_{0^\circ C.}$.

§ 6. *The results* of the isothermal measurements are collected in table I—III. The values $pv_{A\,calc.}$ were calculated with the values of the virial coefficients given in § 7.

Each experimental point is the result of 4 complete measurements, for the 100° C. isothermal several points even of 6 measurements.

§ 7. *The second virial coefficients*. For calculating the values of B the normal volume point was added to each isothermal as given in the tables I—III. For practical reasons the normal volume had been measured at 18° C. and 1 atm. The most accurate method for reduction to 0° C. is by means of the expansion coefficient $\overset{0-18^\circ C.}{\alpha_p}$. The result was:

before the isothermal measurements:	548.834 cm^3.
after ,, ,, ,, :	548.888 ,,
average	548.861 $\pm$ 0.027

The most accurate reduction to 100° C. is obtained by starting from the 0° C. value and calculating with the pressure coefficient $\overset{0-100^\circ C.}{\alpha_v}$ at 1 atm. So for the normal volume points in terms of the normal volume we took

	p	d_A	pv_A
0° C.	1	1	1
20° C.	1	$\dfrac{1}{1+20\overset{0-20^\circ C.}{\alpha_p}}$	$1+20\overset{0-20^\circ C.}{\alpha_p}$
100° C.	$1+100\overset{0-100^\circ C.}{\alpha_v}$	1	$1+100\overset{0-100^\circ C.}{\alpha_v}$

[1]) See the reference quoted note 4, p. 814.

TABLE I. Isothermal of helium for 20 °C.

Date	N⁰.	p	d_A	$pv_{A\ obs}$	$pv_{A\ calc}$	$(O-C)\times 10^{+5}$
20 May 1932	1	5.56381	5.17472	1.07519	1.07543	— 24
	2	6.20789	5.77113	1.07568	1.07575	— 7
	3	7.00056	6.50508	1.07617	1.07614	+ 3
	4	8.02048	7.44873	1.07676	1.07665	+ 11
	5	9.36486	8.69399	1.07716	1.07732	— 16
	6	11.25379	10.43667	1.07829	1.07825	+ 4
	7	12.20866	11 31811	1.07868	1.07872	— 4
	8	13.20781	12.23975	1.07909	1.07921	— 12
21 May 1932	1	13.24637	12.27430	1.07920	1.07923	— 3
	2	12.22852	11.33568	1.07876	1.07873	+ 3
	3	21.24266	10.42416	1.07852	1.07824	+ 28
	4	9.28986	8.62351	1.07727	1.07728	— 1
	5	8.03029	7.45662	1.07693	1.07665	+ 28
	6	7.00595	6.50940	1.07628	1.07615	+ 13
	7	6.21259	5.77497	1.07578	1.07575	+ 3
	8	5.56797	5.17842	1.07523	1.07543	— 20
24 May 1932	1	13.28507	12.31087	1.07913	1.07925	— 12
	2	12.22516	11.33350	1.07867	1.07873	— 6
	3	11.26387	10.44485	1.07841	1.07825	+ 16
	4	9.40695	8.73317	1.07715	1.07734	— 19
	5	8.03753	7.46413	1.07682	1.07666	+ 16
	6	7.02271	6.52494	1.07629	1.07615	+ 14
	7	6.21839	5.78038	1.07578	1.07576	+ 2
	8	5.57559	5.18583	1.07516	1.07544	— 28

For this calculation we accepted:

$$\overset{0-20^\circ\,\mathrm{C.}}{\alpha_p} = \alpha_A + \frac{B_{20^\circ\,\mathrm{C.}} - B_{0^\circ\,\mathrm{C.}}\,(1 + 20\,\alpha_A)}{20} = 0{,}00365996 \quad . \quad . \quad (5)$$

$$\overset{0-100^\circ\,\mathrm{C.}}{\alpha_v} = 0{,}0036609 \text{ for 1 m mercury [1]}$$
$$= 0{,}00366101 \text{ for 1 atm.}$$

[1]) W. H. KEESOM, A. BIJL and Miss H. VAN DER HORST, l.c. p. 813, note 1.

TABLE II. Isothermal of helium of 0° C.

Date	N⁰	p	d_A	$pv_{A\,obs}$	$pv_{A\,calc}$	$(O-C)\times 10^{+5}$
26 May 1932	1	12.43204	12.36263	1.00561	1.00570	— 9
	2	11.48274	11.42075	1.00543	1.00522	+ 21
	3	10.65493	10.60214	1.00498	1.00481	+ 17
	4	8.98078	8.94453	1.00405	1.00398	+ 7
	5	7.69834	7.67063	1.00361	1.00334	+ 27
	6	6.76536	6.74596	1.00288	1.00287	+ 1
	7	6.01487	6.00120	1.00228	1.00250	— 22
27 May 1932	1	12.45699	12.38790	1.00558	1.00571	— 13
	2	12.46478	12.39543	1.00559	1.00571	— 12
	3	11.48867	11.42802	1.00531	1.00523	+ 8
	4	10.63712	10.58771	1.00467	1 00481	— 14
	5	8.94029	8.90267	1.00423	1.00396	+ 27
	6	7.70675	7.67917	1.00359	1.00334	+ 25
	7	6.75635	6.73732	1.00282	1.00287	— 5
	8	6.02039	6.00632	1.00234	1.00250	— 16
1 June 1932	1	6.05938	6.04541	1.00231	1.00252	— 21
	2	6.76787	6 74906	1.00279	1.00288	— 9
	3	7.71382	7.68803	1.00335	1.00335	0
	4	8.95584	8.92043	1.00397	1.00397	0
	5	10.64405	10.59301	1.00482	1.00481	+ 1
	6	11.50026	11.44048	1.00523	1.00523	0
	7	12.38806	12.32015	1.00551	1.00568	— 17

We then calculated the values of A_A and B_A according to equation (4*b*) by means of least squares, giving the normal volume points an appropriate weight [1]). The results are given in Table IV.

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[1]) As the accuracy of the normal volume is about 1 : 20000, that of the individual points of the isothermals about 1 : 10000, we gave the normal volume points a weight 4, the 0° and 20° isothermal points the weight 1. In connection with the smaller densities of the gas in the bulb, which occurred at 100° C., we gave the 100° C. isothermal points a weight proportional to the density in the bulb and the corresponding normal volume point a weight 4 times that of the point at highest density.

TABLE III. Isothermal of helium of 100° C

Date	N⁰.	p	d_A	$pv_{A\,obs}$	$pv_{A\,calc}$	$(O-C)\times 10^{+5}$
12 May 1932	1	16.49988	12.01478	1.37330	1.37336	− 6
	2	15.03701	10.95345	1.37281	1.37266	+ 15
	3	13.55238	9.87678	1.37215	1.37196	+ 19
	4	10.92736	7.97280	1.37058	1.37070	− 12
	5	9.14228	6.67207	1.37023	1.36985	+ 38
	6	7.84993	5.73206	1.36948	1.36923	+ 25
	7	6.85434	5.00802	1.36867	1.36875	− 8
	8	6.08779	4.44879	1.36841	1.36839	+ 2
13 May 1932	1	16.53931	12.04401	1.37324	1.37338	− 14
	2	15.02817	10.94735	1.37277	1.37266	+ 11
	3	13.61973	9.92818	1.37182	1.37199	− 17
	4	10.94098	7.98359	1.37043	1.37071	− 28

§ 8. As one of us [1]) already communicated formerly, preliminary measurements had been made with small reservoirs of Thüringen glass. Isothermals of 100° C., however, could not be made with them, because of the bursting of the reservoirs by heating with steam. For different reasons the results obtained by these experiments have not quite the same accuracy as those dealt with above. We give the results in table V, as they can serve as a valuable check, diminishing the chance of systematic errors.

TABLE V.

	0° C.	20° C.
A_A	0.999583	1.07273
B_A	$0.504^6 . 10^{-3}$	$0.529^4 . 10^{-3}$
B	$0.504^8 . 10^{-3}$	$0.493^5 . 10^{-3}$

The agreement with the values of Table IV is very satisfactory. We consider those of table IV as the definitive ones.

[1]) Cf. p. 814 note 4.

TABLE IV. Virial coefficients of helium.

	0° C.	20° C.	100° C.
A_A	0.999485	1.072662	1.365465
B_A	$0.5025 . 10^{-3}$	$0.5352 . 10^{-3}$	$0.6573 . 10^{-3}$
B	$0.5028 . 10^{-3}$	$0.4989 . 10^{-3}$	$0.4814 . 10^{-3}$
$B_{100^\circ C.} - B_{0^\circ C.} = -0.021^4 . 10^{-3}$			

§ 9. *Comparison with previous results.*

a. In view of the importance which the value of $B_{100^\circ C.} - B_{0^\circ C.}$ has for thermometry (cf. § 2), and as the accuracy obtained for $B_{100^\circ C.} - B_{0^\circ C.}$ is greater than that obtained for $B_{100^\circ C.}$ and $B_{0^\circ C.}$ separately, we compare the existing values of $B_{100^\circ C.} - B_{0^\circ C.}$ in Table VI.

Relative to this table the following remarks are to be made.

KAMERLINGH ONNES calculated B from his measurements using estimated values of C. We recalculated the KAMERLINGH ONNES values using the values of C deduced from measurements by HOLBORN and OTTO [2]).

For the Berlin values we chose the coefficients given by the authors

TABLE VI.

	$B_{0^\circ C.} \times 10^3$	$B_{100^\circ C.} \times 10^3$	$(B_{100^\circ C.} - B_{0^\circ C.}) . 10^3$
KAMERLINGH ONNES [1])	0.505^6	0.484^1	-0.021^5
HOLBORN and OTTO [2])	0.529	0.513	-0.016
WIEBE, GADDY and HEINS [3])	0.521^7	0.504^4	-0.017^3
KEESOM and VAN SANTEN	0.502^8	0.481^4	-0.021^4

mentioned for a series in powers of v^{-1}, recalculating them for our unit of pressure. If one starts from the coefficients in powers of p [4]) one obtains:

HOLBORN and OTTO: $B_{0^\circ C.} = 0.529 \times 10^{-3}$, $B_{100^\circ C.} = 0.508 \times 10^{-3}$, $B_{100^\circ C.} - B_{0^\circ C.} = 0.021 \times 10^{-3}$.

If, however, we do the same from the latest Berlin coefficients (given

[1]) H. KAMERLINGH ONNES. These Proceedings, **10**, 445, 1908. Comm. N⁰. 102*a*.

[2]) L. HOLBORN und J. OTTO. Zs. f. Phys. **10**, 367, 1922, calculated from measurements of: L. HOLBORN und H. SCHULTZE Ann. d. Phys. (4) **47**, 1089, 1915.

[3]) R. WIEBE, V. L. GADDY and C. HEINS. J. Amer. Chem. Soc. **53**, 5, 1931.

[4]) L. HOLBORN und J. OTTO. Zs. f. Phys. **38**, 365, 1926.

for a series in powers of p) we obtain: J. OTTO [1]): $B_{0°C.} = 0.524^4 \times 10^{-3}$, $B_{100°C.} = 0.5078 \times 10^{-3}$, $B_{100°C.} - B_{0°C.} = 0.017 \times 10^{-3}$ [2]).

Hence the comparison with the Berlin values is not conclusive as to the last decimal of $B_{100°C.} - B_{0°C.}$; the agreement of the results obtained by the different experimenters is, however, well within the limit of accuracy mentioned in § 5.

b. In behalf of the comparison of the values of B themselves we add in Table VII, for completing Table VI, the values of B obtained by observers who did not measure both values $B_{0°C.}$ and $B_{100°C.}$.

TABLE VII.

	$B_{0°C.} \times 10^3$	$B_{20°C.} \times 10^3$	$B_{25°C.} \times 10^3$	$B_{100°C.} \times 10^3$
BOKS and KAMERLINGH ONNES [3])	0.523	0.512		
HEUSE and OTTO [4])	0.520			
TANNER and MASSON [5])			0.515	0.498
KEESOM and VAN SANTEN	0.503	0.499		0.481

As to TANNER and MASSON's values we observe that from a curve representing their results $B_{0°C.} = 0.523 \times 10^{-3}$, $B_{100°C.} = 0.495 \times 10^{-3}$, would follow.

We conclude that the differences between the results obtained by different observers for the absolute values of B are somewhat larger than the mean error we estimated in § 5 for our results.

§ 10. By using our value $B_{100°C.} - B_{0°C.} = -0{,}0214 \times 10^{-3}$, and KEESOM, BIJL and Miss VAN DER HORST's value (cf. § 7) $\overset{0-100\,C.}{\alpha_v} = 0{,}0036609$ for 1 m mercury, we derive

$$\alpha_A = 0{,}00366130$$

$$T_{0°C.} = 273.12^7.$$

As, however, still new measurements of the pressure coefficient of helium are going on (cf. § 1), these numbers are still to be considered as preliminary ones.

We gladly record our thanks to phil. nat. docts. H. H. KRAAK for his valuable help at the experiments.

[1]) J. OTTO. Zs. f. Instrumentenkunde 48, 257, 1928.

[2]) Cf. LANDOLT—BÖRNSTEIN, 2er Erg. bd. I, 44.

[3]) J. D. A. BOKS and H. KAMERLINGH ONNES. Comm. N°. 170a. The values of B we are calculated by G. P. NIJHOFF. Thesis Leiden 1928, p. 42.

[4]) W. HEUSE und J. OTTO. Zs. f. Instrumentenkunde 49, 267, 1929.

[5]) C. C. TANNER and I. MASSON, Proc. Roy. Soc. (A) 126, 268, 1930.

Physics. — *On an apparatus for rectifying small quantities of liquefied gas, and on the purification of krypton.* By H. VAN DIJK, J. MAZUR and W. H. KEESOM. (Communication N⁰. 228 from the KAMERLINGH ONNES Laboratory at Leiden.)

(Communicated at the meeting of September 30, 1933).

Summary. An apparatus is described with which it is possible to purify a relatively small quantity of gas by rectification according to CLAUDE's principle of "retour en arrière". This method has been tested for the purification of krypton and satisfactory results have been obtained.

§ 1. *Introduction.* A method which is much used for the purification of gases that cannot easily be separated by chemical means, is that of condensation followed by fractional evaporation. In this method condensation is performed at a temperature at which the gas to be separated has a small, the more volatile admixtures, however, still have an appreciable vapour pressure. The latter are then drawn off by exhausting, after which the condensate is evaporated slowly, the fraction which evaporates last being eliminated.

If necessary the process can be repeated with the middle fraction. This method has, however, the difficulty that the middle fraction, which is evaporated at a higher temperature, will contain on one hand that portion of the more volatile admixtures that was solved or occluded in the (in most cases solid) condensate, on the other hand a part of the heavier impurities that already have again an appreciable vapour pressure at that temperature. This difficulty can be avoided if at a properly chosen temperature a rectification is performed. Theoretically, to obtain this result completely, one should need an infinitely long rectification column, and the different fractions should have to be drawn off infinitely slowly. Hence in practice a certain compromise has to be chosen. It may appear, however, that in many cases one can obtain a quite satisfactory result with an apparatus of practical dimensions and within a practical time.

The desirability to test this became evident when in behalf of measurements of saturated vapour pressures of krypton, to be followed by determinations of liquid and vapour densities, it was needed to separate a quantity of very pure krypton from a sample of gas which by the kind intermediary of Prof. MATHIAS was put at the disposition of the KAMERLINGH ONNES Laboratory by G. CLAUDE. It had appeared that the method of condensation and fractional evaporation did not yield the desired result. A happy circumstance was that in behalf of the further separation of hydrogen isotopes by rectification [1]) an apparatus had been designed

[1]) Cf. W. H. KEESOM and H. VAN DIJK, These Proceedings 36, 248, 1933. Comm. Leiden, N⁰. 224*a*.

and already tested with which rather small quantities of liquefied gas can be rectified. We decided to undertake with it the purification of the quantity of krypton at hand, partly as a test and a first application of this method of purification of gases, and further in order to obtain in this way a quantity of krypton of the desired purity.

§ 2. *Purification of krypton by fractional evaporation.* The apparatus is represented in Fig. 1. The krypton from the bulbs *A, B* etc. in which it was furnished by the Société l'Air Liquide, was slowly passed through the

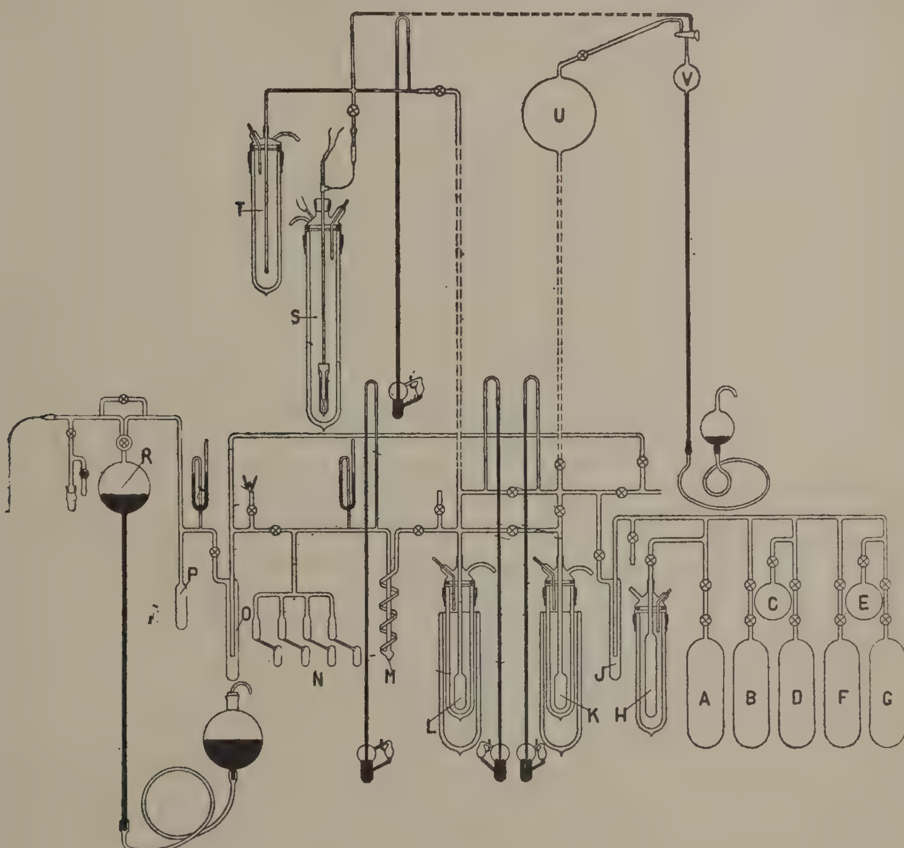

Fig. 1.

trap *J* refrigerated by alcohol cooled by liquid air to a temperature of —115° C, in order to freeze out water and carbon dioxide, and condensed into *K* kept cold by liquid oxygen. After lowering the temperature to —205° C by reduction of the pressure above the liquid oxygen, the pressure above the solid krypton was 2 cm mercury. The gas above the solid krypton was then exhausted during 10 minutes, after which the remaining pressure was 0.5 cm. Then *L* was slowly cooled with liquid oxygen and the middle fraction from *K* condensed into it. The gas above the solid krypton in *L*

was exhausted at —210° C till no measurable pressure remained. The middle fraction evaporating from L was collected in R. This process was repeated after having transferred the gas to H with the aid of liquid hydrogen.

A spectroscopic test by means of a large STEINHEIL glass spectrograph, 2 mm pressure in the GEISSLER tube with external electrodes, revealed, in the range between 5876 and 4140 Å, some sixty lines which all were identified as krypton lines, except two which were due to xenon. Of oxygen or nitrogen no trace was found in this way.

The vapour pressure curve of the krypton so obtained showed, however, an anomaly at about —185° C (cf. § 3*b*). So it was decided to see whether by rectification possibly a purer sample of gas might be obtained.

§ 3. *Purification of krypton by rectification.*

a. The rectifying apparatus was taken up already in Fig. 1 and is represented in detail in Fig. 2. Its working principle is that of the socalled "retour en arrière" used by CLAUDE in the rectification of air. The vapour formed in the still K by using the heating coil S is condensed along the windings of a copper screw R. The liquid formed streams back along these windings and partly also along the inner wall of the DEWAR vessel. The condensation heat is conducted at the top of the apparatus to the liquid at the outside.

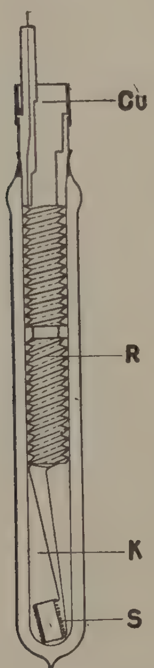

Fig. 2.

As the DEWAR vessel is unsilvered one can easily control the rectification process and properly adjust the heat production in the coil. The apparatus, which had been designed in behalf of the rectification of hydrogen (cf. § 1), was tested first by rectifying mixtures of oxygen and nitrogen [1]). Having been filled with a mixture containing about 5 % of nitrogen, after an hour's rectifying practically pure nitrogen could be taken off at the top. Chemical analysis of this product showed no oxygen to an amount of 1 %. Hence the rectifying effect was at least equivalent to that of a column of 5 or 6 ideal pans.

b. For a further purification of the sample of krypton mentioned in § 2 the apparatus described under *a* was surrounded by a bath of ethylene kept constantly at a temperature a little above the triple point of krypton. After half an hour's rectification the first fraction of 130 cm³ gas at standard conditions was slowly (2 cm³/min) drawn off. The next fraction (98.5 cm³) was put into the vapour pressure apparatus. A last fraction of 323 cm³ was collected.

The vapour pressure measurements showed clearly that the rectification

[1]) We wish to record our thanks to chem. cand. J. W. BOEHMER for performing this test.

had resulted in an appreciable increase of the purity of the gas. The *log p*, T^{-1}-curve (p in mm Hg.) now showed no abnormal variation of the slope, *vide* Fig. 3, where the dashed line (- - - -) refers to measurements on the sample purified by fractional evaporation, the full line (——) to those

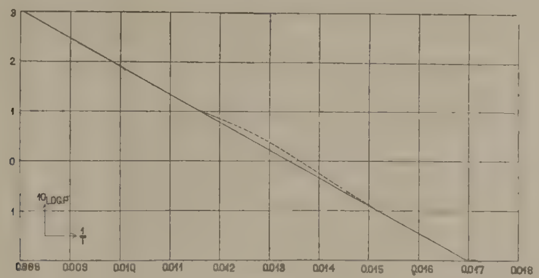

Fig. 3.

on the sample purified by rectification. Numerical data concerning the vapour pressures of krypton will be given in a subsequent paper.

To check the purity of the gas now obtained the middle and the last fractions mentioned above were added together [1]) and rectified again in an apparatus as described under *a*, but of smaller dimensions. In this apparatus the double-speeded screw was 4 cm long, diameter 8 mm, depth of the thread 1,5 mm. The vapour pressures of the middle fraction obtained by this new rectification coincided with those of the product of the first rectification. We conclude that rectification is a much more effective method of purification than fractional evaporation.

1) Rectifying the middle portion alone was prohibited by its small quantity.

Physics. — *On the adsorption of neon on glass at liquid hydrogen temperatures.* By W. H. KEESOM and G. SCHMIDT. (Communication N⁰. 226*a* from the KAMERLINGH ONNES Laboratory at Leiden.)

(Communicated at the meeting of September 30, 1933).

Summary. Measurements have been made on the adsorption of neon on glass at four temperatures in the liquid hydrogen range. It appeared that in increasing the pressure the covering of the wall proceeds regularly and that complete covering with a monomolecular layer is reached at about the saturated vapour pressure. The adsorption isotherms are represented pretty well by the formula :

$$q^3 = \frac{p}{0.7\,(p_s - p) + p},$$

q being the fraction of the wall covered, p the pressure, p_s the saturated vapour pressure.

§ 1. *Introduction.* When trying to measure temperatures below 1°K. by means of a helium thermometer with an ice point pressure of 1 mm mercury, it appeared that already below 4°K. the pressure decreased too rapidly, and that at 0.73°K. (derived from the vapour pressure of the liquid

helium) the pressure in the thermometer had nearly vanished. We realised that a complete monomolecular covering of the inner wall was just sufficient to take up nearly all the helium present.

This experience induced us to make an examination of the adsorption of helium on glass at liquid helium temperatures. We decided, however, to start with an investigation of the adsorption of neon at liquid hydrogen temperatures.

For the different theories of adsorption we refer to LANGMUIR [1]), MAGNUS and others [2]).

Measurements have been made on argon, nitrogen, oxygen and carbon monoxide, on glass and on mica, already by LANGMUIR. The experimental material is, however, not yet sufficient to get a good survey of the course of the adsorption isotherm over the whole range.

Of the noble gases, of which one can feel sure that adsorption has a purely physical character, only argon has been investigated with respect to glass and mica [1]). The measurements are, however, incomplete.

Measurements of the adsorption of neon, helium, and hydrogen by a perfectly smooth surface, such as a glass wall, are completely lacking. Only some measurements on adsorption by charcoal have been made.

It is in the first place interesting to examine for these gases how the covering of a glass wall with adsorbed gas proceeds if an adsorption isotherm is followed till saturation sets in. This paper deals with such an examination for neon. In a following paper some results about helium will be communicated.

§ 2. *The apparatus.* Our method consisted in comparing the pressures of two gasthermometers (Fig. 1), identical as to the volumes of the different parts, but different as to the glass surface. For this purpose the thermometer T_1 had been filled with a large number of thinwalled glass capillaries of which the total surface and the glass volume were known. The remaining volume was as nearly as possible equal to that of T_2.

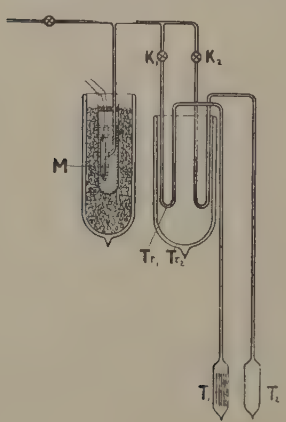

Fig. 1.

The thermometer spaces could be connected by the cocks K_1 and K_2 respectively with a common manometer space, the pressure of which could be measured with a hot wire manometer M immersed in an ice bath. The volume of this manometer space could be considered as a relatively small dead space.

The two capillaries were identically bent to small moisture traps Tr_1, Tr_2 cooled with liquid air. The thermometers and the capillaries were taken from the same tube of Thüringen glass.

[1]) I. LANGMUIR, Journ. Amer. Chem. Soc. 40, 1361, 1918.
[2]) Trans. Far. Soc. 28, 131—394, 1932.

Gas volume in the thermometerbulb: 5.426 cm³ (20° C), inner diameter thermometer capillary: 2.05 mm, inner glass surface of T_1: 266 cm².

§ 3. *The measurements.* For outgassing the cocks, the thermometer and manometer spaces were kept at high vacuum during several days before a series of measurements was to be made. The remaining gas development could be controlled with the hot wire manometer.

The last day before the measurements both thermometer bulbs together with large parts of the capillaries were heated to 340°C. for several hours. During this operation the moisture traps were surrounded by liquid air; they remained so till on the next day the measurements had been finished. On this day the hot wire manometer was compared with an accurately calibrated Mc Leod gauge.

A series of measurements proceeded as follows. When both thermometers had been highly evacuated, the cocks K_1 and K_2 were closed. Then the manometer space was filled by connecting it with a neon container of about 3 l capacity held at constant temperature. Alternately such a filling was introduced into each of the thermometer bulbs.

If there had been no adsorption, the pressures of the two thermometers would have increased with equal amounts. The adsorption manifested itself by the difference in increase of the pressure of the two thermometers.

In this way we could rather rapidly take a complete series of points of an adsorption isotherm.

The manometer volume was so small compared with the thermometer volume, that practically at each step the same quantity of gas was introduced into the thermometer. When necessary a small correction was applied.

This made it possible to determine in a simple way the thermomolecular pressure difference. For determining the pressure obtained in thermometer T_2 after a large number of fillings, we consider the thermomolecular pressure difference, which in this case is small, as being sufficiently well known. Neglecting the adsorption in T_2 we can then calculate the pressures in T_2 after the different fillings. By comparison with the values given by the hot wire manometer we get the thermomolecular pressure difference as a function of pressure. After having calculated the adsorption in T_2 a correction for the small adsorption in T_2 can be applied.

In our case this determination of the thermomolecular pressure difference served rather as a control because we could already dispose of an extended experimental material *i.a.* for neon (to be published before long).

After the measurements the hot wire manometer was again compared with the Mc Leod gauge.

We checked the purity of our neon by filling thermometer T_2 with neon to saturation and seeing whether the pressure increased if more neon was introduced. The small pressure increase which occurred (at constant tem-

perature) pointed to a small admixture of helium which, however, is of no importance for our results.

§ 4a. *The results* have been collected in table I. It gives the equilibrium gas density as a function of the fraction of the wall that is

TABLE I.

Adsorption of neon on glass							
$T = 20.28$ °K. $p_s = 35.6$ mm Hg		$T = 16.99$ °K. $p_s = 3.93$ mm Hg		$T = 15.86$ °K. $p_s = 1.51$ mm Hg		$T = 14.45$ °K. $p_s = 0.294$ mm Hg	
p (mm Hg)	q	p (mm Hg)	q	p (mm Hg)	q	p (mm Hg)	q
0.0471	0.106	0.0149	0.223	0.0017	0.138	0.0015	0.133
0.103	0.140	0.0525	0.312	0.0085	0.292	0.0051	0.296
0.163	0.179	0.0967	0 356	0.0255	0.389	0.0146	0.417
0.227	0.196	0.445	0.540	0.0482	0.438	0.0311	0.500
0 289	0.212	0.818	0.621	0.118	0.549	0.0524	0.556
0.347	0.232	1.192	0.680	0.193	0.620	0.0760	0.587
0.407	0.251	1.557	0.749	0.279	0.690	0.0952	0.660
0.469	0.260	1.931	0.790	0.404	0.741	0.120	0.700
0.530	0.265	2.294	0.855	0.522	0.807	0.144	0.753
0.601	0.275	2.656	0.913	0.648	0 828	0.166	0.789
0.763	0.312			0.763	0.862	0.187	0.823
				0.882	0.904	0.221	0.858
				0 997	0.943	0.237	0.892
				1.116	0.967	0.259	0.922
				1.232	0.978	0.282	0.945
				1.340	0.990		
				1.446	1.001		

covered with adsorbed gas. Instead of the gas density itself, the gas pressure p is given which corresponds with this density at 20.28°K. (obtained by multiplying the real pressure by $20.28/T$) [1]). p_s is in the same scale, *i.e.* measured as a pressure at 20.28°K., the saturated vapour density. The number q, which indicates the fraction of the wall covered, is obtained by dividing the quantity of gas adsorbed by the quantity which would correspond to a monomolecular layer covering the wall. This monomolecular

[1]) Deviations from the ideal gas laws may be neglected here.

layer is supposed to consist of spheres arranged in closest packing. For the diameter of the spheres 2.3×10^{-8} cm [1]) has been taken.

Fig. 2 shows the course of the 4 adsorption isotherms measured. The measurements were continued for the lowest three temperatures till con-

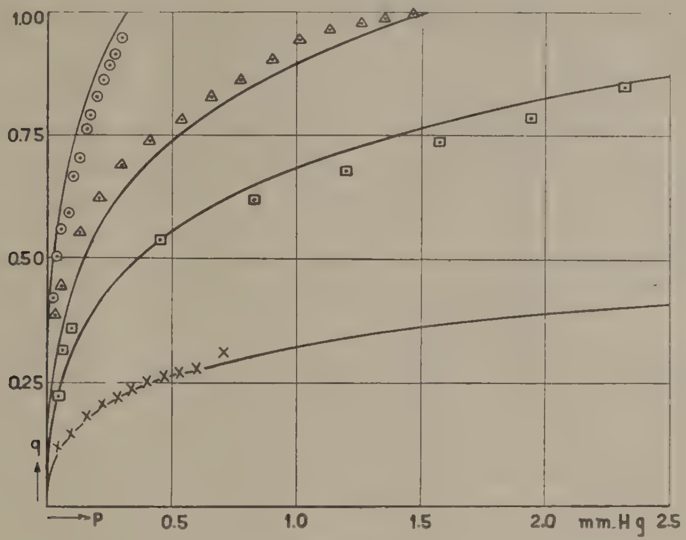

Fig. 2.

densation set in. The vapour pressures then observed were somewhat larger than CROMMELIN and GIBSON's [2]) values. Leaving open the question whether this difference is real or a consequence of the small admixture of helium referred to in § 3, we calculated the "saturation densities" mentioned in table I and used for checking equation (3) of § 5 with our values, these being the saturation pressures valid for the gas we experimented on.

b. Fig. 2 shows in the first place how the amount of covering of the wall in the range of unsaturated gas density everywhere remains below that by a complete monomolecular layer. This agrees with what LANGMUIR (l.c.) and after him other observers found in cases in which we have to do with a purely physical phenomenon and the gas has no prominent dipole character. It further shows that complete monomolecular covering seems to be reached near the saturation density.

It must be remarked that this conclusion depends on two assumptions, *viz.* that of closest packing arrangement of the adsorbed layer, and that of perfect smoothness of the wall, which probably are not quite correct. There may be some small space between the adsorbed atoms on one hand, the real wall surface probably will be some percentages larger than the geometrical surface we have reckoned with on the other hand. These two circumstances will partly cancel one another.

1) A. O. RANKINE, Phys. Zs. **11**, 745, 1910.

2) C. A. CROMMELIN and R. O. GIBSON, These Proc., **36**, 362, 1927; Comm. N°. 185*b*.

Apart from this uncertainty especially the two point series corresponding to $T = 14.45°$K. and $T = 15.86°$K. point to the remarkable coincidence we mentioned.

§ 5. *Discussion.* *a.* These adsorption measurements were performed on glass with a view to gas thermometry. From a theoretical standpoint glass is, notwithstanding its smooth surface, not a very appropriate adsorbent, because of the very inhomogeneous structure of its surface. A further research on the adsorption of noble gases, and jointly of dipole gases, by glass covered with a monomolecular gas or with a metallic layer may be considered to be of very great importance for theory.

b. The inhomogeneous structure of the surface joined to the fact that glass is a non-conductor for electricity make, that a further elaboration of the electric theory [1]) of adsorption for it will have grave difficulties. The problem of the attraction between a noble gas atom and the glass wall will be very much like that of the VAN DER WAALS' forces.

We refrain from considering the nature of the adsorption forces and further discuss our results in terms of LANGMUIR's theory [2]).

For a wall with one kind of "elementary spaces" LANGMUIR deduces his well-known equation

$$q = \frac{c_1 c_2 p}{1 + c_2 p}, \quad \ldots \ldots \ldots \ldots \quad (1)$$

in which q is the fraction of the wall covered, p the gas pressure, c_1 and c_2 are constants. $c_1 \leqq 1$. c_2 is proportional to the mean average life of the adsorbed molecules on the wall, which is supposed to be independent of the gas pressure.

A glass surface may be considered as consisting of different parts each with one particular kind of "elementary spaces". Then the equation of the adsorption isotherm will obtain a second member built up by a number of terms as in (1) each with its proper constants. At increasing pressure these parts will successively become saturated. Hence the mean average life for the surface as a whole will decrease with increasing pressure. Instead of trying such a complicated equation, which would possess many constants for our material, we confine ourselves to observing that equation (1) very well enables us to represent our adsorption isotherms for neon for values of $q < 0.5$, provided we express the dependence of the average life on the pressure by introducing c_2/q^2 instead of c_2.

So far our results may be considered to agree with LANGMUIR's theory.

c. For the range of larger degrees of covering, $q > 0.5$, our isotherms definitely show another course than might be expected from LANGMUIR's theory.

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1) A. MAGNUS, l.c.

2) I. LANGMUIR, l.c.

As far as we know, gases as Ne, Ar, He, N_2, O_2 and H_2 have never been investigated before as to adsorption near to saturation, at least not on a perfectly smooth surface.

Coal as adsorbent is in this respect to be objected to, as capillary adsorption ought to be avoided for comparing with LANGMUIR's theory.

In our experiments capillary condensation could occur at very narrow strips of the exterior walls of the small tubes, where they are in contact with each other. Only for so far as the interspace between two tubes in contact has molecular dimensions, capillary adsorption can occur. Hence these strips are so narrow that their total surface may be neglected, even if covering with a multimolecular layer were supposed.

Our measurements for the range of larger degrees of covering point to a certain connection between the attainment of saturation in the adsorbed film and of saturation in the gas.

LANGMUIR's equations do not suppose this connection. This is a consequence of the fact that LANGMUIR neglects the average life of incident molecules on already adsorbed molecules. This may be practically right for small degrees of covering, it is questionable whether it is also right for larger amounts of covering. Neglecting this average life at larger gas densities is in fact equivalent to neglecting the VAN DER WAALS' forces between the molecules and the wall. In reaching saturation the VAN DER WAALS' forces, however, play an all important rôle.

Independently of the special theory we may form about gas condensation, we shall have to assume that when condensation begins groups of molecules will take up colliding molecules with a certain average life.

As it seems rather difficult to express this influence in an exact way, we tried to account for it by dividing p by $p_s - p$ (p_s referring to saturation pressure), so that equation (1), introducing also c_2/q^2 for c_2 as explained in b, changes to

$$q = \frac{c_1 c_2 p}{q^2 (p_s - p) + c_2 p}.$$

For the sake of simplicity we replaced, in the denominator, $c_2 p$ by $c_2 p q^2$. This change has only a small influence, as for small values of q p is very small, so that the first term in the denominator is by far preponderant, whereas for small values of $p_s - p$, so that the first term is preponderant, q approaches to 1.

Taking into account that for $p_s - p = 0$, $q = 1$, the formula may then be written as follows

$$q^3 = \frac{p}{k (p_s - p) + p} \quad . \; . \; . \; . \; . \; . \; . \; . \; . \quad (2)$$

The curves in fig. 2 represent the isotherms calculated with

$$q^3 = \frac{p}{0{,}7 (p_s - p) + p} \quad . \; . \; . \; . \; . \; . \; . \; . \; . \quad (3)$$

We recognize that this formula not only fairly well agrees with the experimental results for the individual isotherms, but that it also accounts in a satisfactory degree for the dependence of the adsorption on temperature.

Physics. — *Measurements on the adsorption of helium on glass at liquid helium temperatures.* By W. H. KEESOM and G. SCHMIDT. (Communication N⁰. 226*b* from the KAMERLINGH ONNES Laboratory at Leiden.)

(Communicated at the meeting of September 30, 1933).

Summary. The adsorption of helium on glass was investigated at liquid helium temperatures. The results can be represented fairly well by the formula

$$q^4 = \frac{p}{0{,}26\,(p_s - p) + p}.$$

One measurement on the adsorption of hydrogen at 15.1°K. was made.

It was tried to make helium thermometer measurements below 1°K. possible by adding some neon. This procedure did not lead to success.

§ 1. *The measurements* of the adsorption of helium on glass were made after the same method as those of the adsorption of neon dealt with in the preceding paper [1]). They are somewhat less accurate because of the large thermomolecular pressure differences that occurred in these experiments. These pressure differences were measured in the same way as described in § 3 of the preceding paper.

Dimensions of the apparatus:

volume thermometer bulb 4.356 cm³,
supplementary surface of glass capillaries 133 cm²,
internal diameter thermometer capillary 1.20 mm.

The whole apparatus was made of Thüringen glass.

§ 2. *The results* have been collected in table I.

p represents the gas density, measured as the pressure the gas would exert in the same volume at the temperature 4.22°K. q is the quantity of gas adsorbed divided by the quantity necessary to cover the glass wall with a monomolecular layer of helium atoms arranged as spheres of diameter 1.9×10^{-8} cm [2]) in closest packing.

Each set of values in table I is an average of 3 to 4 observations.

The results have been represented in fig. 1.

It appears that the behaviour of helium is quite similar to that of neon (cf. fig. 2 of Comm. N⁰. 226*b*).

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[1]) W. H. KEESOM and G. SCHMIDT, These Proceedings **36**, 825, 1933, Comm. Leiden. N⁰. 226*b*.

[2]) W. SUTHERLAND, Phil. Mag. (6) **19**, 25, 1910.

TABLE I.

Adsorption of helium on glass.			
$T = 3.56$ °K.; $p_s = 427$ mm Hg		$T = 3.06$ °K.; $p_s = 254$ mm Hg	
p mm Hg	q	p mm Hg	q
0.050	0.13	0.075	0.16
0.170	0.18	0.210	0.19
0.380	0.25	—	—
$T = 1.71$ °K.; $p_s = 2.45$ mm Hg		$T = 1.13$ °K.; $p_s = 1.72$ mm Hg	
0.020	0.26	0.010	0.57
0.060	0.28	0.070	0.60
0.140	0.34	0.200	0.73
1.000	0.60	—	—

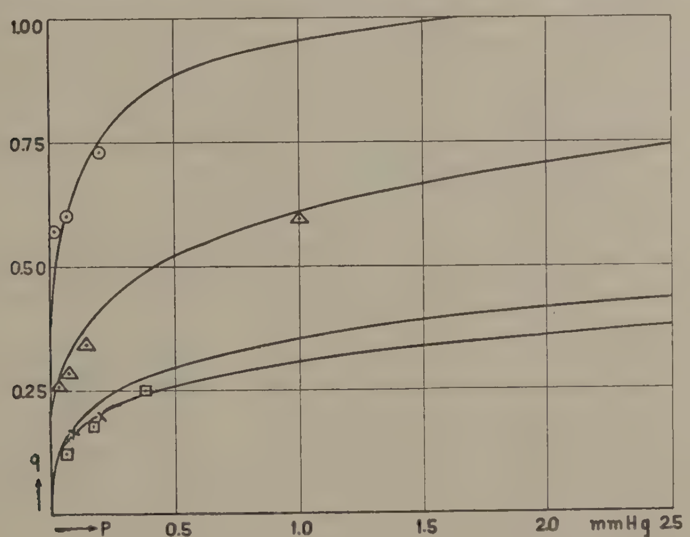

Fig. 1.

⊡ $T = 3.56$ °K. △ $T = 1.71$ °K.
× 3.06 °K. ⊙ 1.13 °K.

The first increase of q for small values of p appears to be somewhat more rapid for helium than for neon. We have expressed this in the formula which gives q as a function of p by raising the exponent of q. We so obtained the equation:

$$q^4 = \frac{p}{0.26\,(p_s - p) + p}.$$

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The full curves in fig. 1 have been drawn according to this formula. It appears that this equation represents the results fairly well.

§ 3. *Remarks.* *a.* In measurements with the helium thermometer below 1°K. adsorption will as a rule necessitate greatly increasing corrections. This is a consequence of the facts that the quantity of gas in the thermometer must be chosen lower and lower, and that for technical reasons the bulb must be taken rather small, which gives an unfavourable ratio between volume and wall surface.

An idea of the prevailing proportions may be obtained from the following instance. If in a sphere with radius 1 cm at 0.9°K. the pressure equals half the saturated vapour pressure, i.e. 0.0025 cm mercury, about 2.5 % of the gas will be absorbed to the wall. For 0.8°K. a similar calculation gives 7.5 %.

For the measurements on the vapour pressures of helium dealt with in Comm. N⁰. 202*c* [1]) the proportions were rather more favourable. For the lowest point, 0.898°K., the pressure in both the thermometers were on an average 0.0025 cm mercury, but the bulbs were about 40 cm^3, so that the ratio volume to wall surface was better. The correction for adsorption will amount to 1.5 % [2]).

For higher temperatures the thermometers were filled to higher pressures, so that there the influence of adsorption remains below 0.1 %.

The limit to which the helium thermometer can be used at the lowest temperatures is determined by adsorption to the wall. It may be considered to lie at 0.8°K. if an accuracy of 1 % is desired. In this estimation we have taken into account that, in view of the available space, the thermometer bulb for such a temperature as a rule will have to be chosen smaller than 1 cm^3.

b. To see whether measurements with a helium thermometer below 0.8°K. might be possible by covering the glass wall with a layer of neon, we made the following experiment.

To the helium we added a quantity of neon amply sufficient to cover the wall with a monomolecular layer. The cooling process was performed in such a way that indeed we could expect that the whole inner wall of the thermometer bulb was covered with neon. It appeared, however, that at such points as mentioned in table I the adsorption of helium was diminished by this procedure to half its original value at the utmost. So this method seems not to lead to success.

c. We made one measurement on the adsorption of hydrogen. We found:

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[1]) W. H. KEESOM, SOPHUS WEBER and G. SCHMIDT, These Proc. **32**, 1314, 1929; Comm. Leiden, N⁰. 202*c*.

[2]) As at the time we did not know the amount of this correction, we did not apply it. It is about the order of magnitude of the experimental error (cf. Comm. N⁰. 219*a*, § 6).

$T = 15.1^\circ$K., $p_s = 11$ cm Hg, $p = 0.165$ mm Hg (reduced to 20.28°K.), $q = 0.12$ (molecular diameter assumed 1.34×10^{-8} cm).

d. An investigation on the adsorption of say hydrogen, neon or helium on a complete monomolecular layer of say nitrogen or argon, or of helium on such a layer of hydrogen might furnish important data with respect to intermolecular forces.

Astronomy. — *Mittlere Lichtkurven von langperiodischen Veränderlichen.* XVI. *T Camelopardalis.* Von A. A. NIJLAND.

(Communicated at the meeting of September 30, 1933).

Instrumente *S* und *R*. Die Beobachtungen wurden alle auf *R* reduziert; die Reduktion *R*—*S* beträgt —0m.30. Spektrum Se (H.A. 79, 166). Gesamtzahl der Beobachtungen 653 (von 2416835 bis 2427332). Es wurden wieder, wie in allen früheren Mitteilungen, die in zwei Instrumenten angestellten Schätzungen nur einmal gezählt.

Karte: HAGEN, *Atlas Stell. var. Series III*; s. auch *Spec. Vat. XII.*

Die Tabelle I giebt eine Übersicht der benutzten Vergleichsterne. Das

TABELLE I. Vergleichsterne.

	BD	HAGEN	St.	HA 74	Grenze	*H*
a	+66°.353	1	59.4	7m.50	—	7m.80
b	+66.345	4	52.3	—	—	8.56
c	+66.334	6	45.8	—	—	9.26
d	—	10	41.3	9.82	—	9.74
e	+65.418	12	35.1	10.62	—	10.40
f	—	18	30.6	—	11m.21	10.88
g	—	22	25.4	11.51	11.35	11.43
h	—	29	20.9	12.06	—	11.91
j	—	35	17.8	12.05	—	12.24
k	—	46	12.2	—	—	12.84
l	—	53	8.9	13.20	—	13.20
n	—	59	6.8	—	—	13.42
p	—	64	0.0	—	13.97	14.14

Spektrum der beiden Sterne *a* und *b* ist Ko (H.A. **92**). Die Sterne *f* und *g* wurden 3-mal (2416994, 7063, 2427154), bezw. 4-mal (2417225, 7233, 2426438, 7154) an die Grenze von *S* angeschlossen, Stern *p* öfters (11-mal), bei der Beobachtung des Veränderlichen im Minimum, an die Grenze von *R*. Die Stufenskala bezieht sich auf die Helligkeit $11^m.0$; der Stufenwert ist $0^m.107$. Der Anschluss an die photometrischen Helligkeiten ist unbefriedigend. So gestattet die sehr oft beobachtete Differenz $ab = 7.1$ Stufen nicht, dem gelben Stern *a* eine viel grössere Helligkeit als $7^m.8$ zu erteilen, obgleich man in H.A. **74** die Grösse $7^m.50$ (Mittel aus zwei Messungen, $7^m.64$ und $7^m.37$) findet, und nach einer brieflichen Mitteilung von weiland G. MÜLLER s.Z. in Potsdam die photometrische Helligkeit zu $7^m.43$ bestimmt wurde. Vielleicht ist der Stern veränderlich.

Es liegen 103 Schätzungen der Farbe vor, welche für fast vier Fünftel aus den Jahren 1905 bis 1911 stammen. Aus der Tabelle II*a* könnte man folgern, dass die Farbe sich fast sprungweise i.J. 1906 geändert hätte. Doch ist zu bemerken, dass die Farben im Anfang meiner Beobachtungstätigkeit überhaupt merklich röter als später notiert wurden. Eine Korrelation mit der Helligkeit ist nicht nachweisbar (Tabelle II*b*). Das allgemeine Mittel ist $3^c.91$.

TABELLEN II*a* und II*b*. Farbenschätzungen.

Zeitraum	*n*	Farbe	Grösse	*n*	Farbe
		c	m		c
2416835—2417326	20	4.42	7.69	13	4.19
7327— 7904	20	3.80	7.92	13	3.69
7916— 8363	20	3.75	8.03	13	3.46
8398— 9155	20	3.68	8.16	13	4.08
9481—2421734	15	3.97	8.42	13	3.81
2423981— 6984	8	3.69	8.66	13	3.96
	103		9.07	13	3.73
			9.86	12	4.33
				103	3.91

Die Figur 1 enthält die Beobachtungen, alle auf *R* reduziert. Die Reihe der Abweichungen (Beobachtung minus Kurve) zeigt 221 Plus-, 234 Minuszeichen, 198 Nullwerte, 198 Zeichenfolgen, 256 Zeichenwechsel. Das Mittel der absoluten Werte der Abweichungen ist $0^m.101$.

Ein Einfluss des Mondscheines auf die Helligkeitsschätzung ist nicht sicher nachweisbar. Es verteilen sich auf 177 bei Mondschein angestellte Beobachtungen die Abweichungen wie folgt: 53 Plus-, 67 Minuszeichen, 57 Nullwerte.

Die Tabelle III enthält die aus der Kurve abgelesenen Epochen der

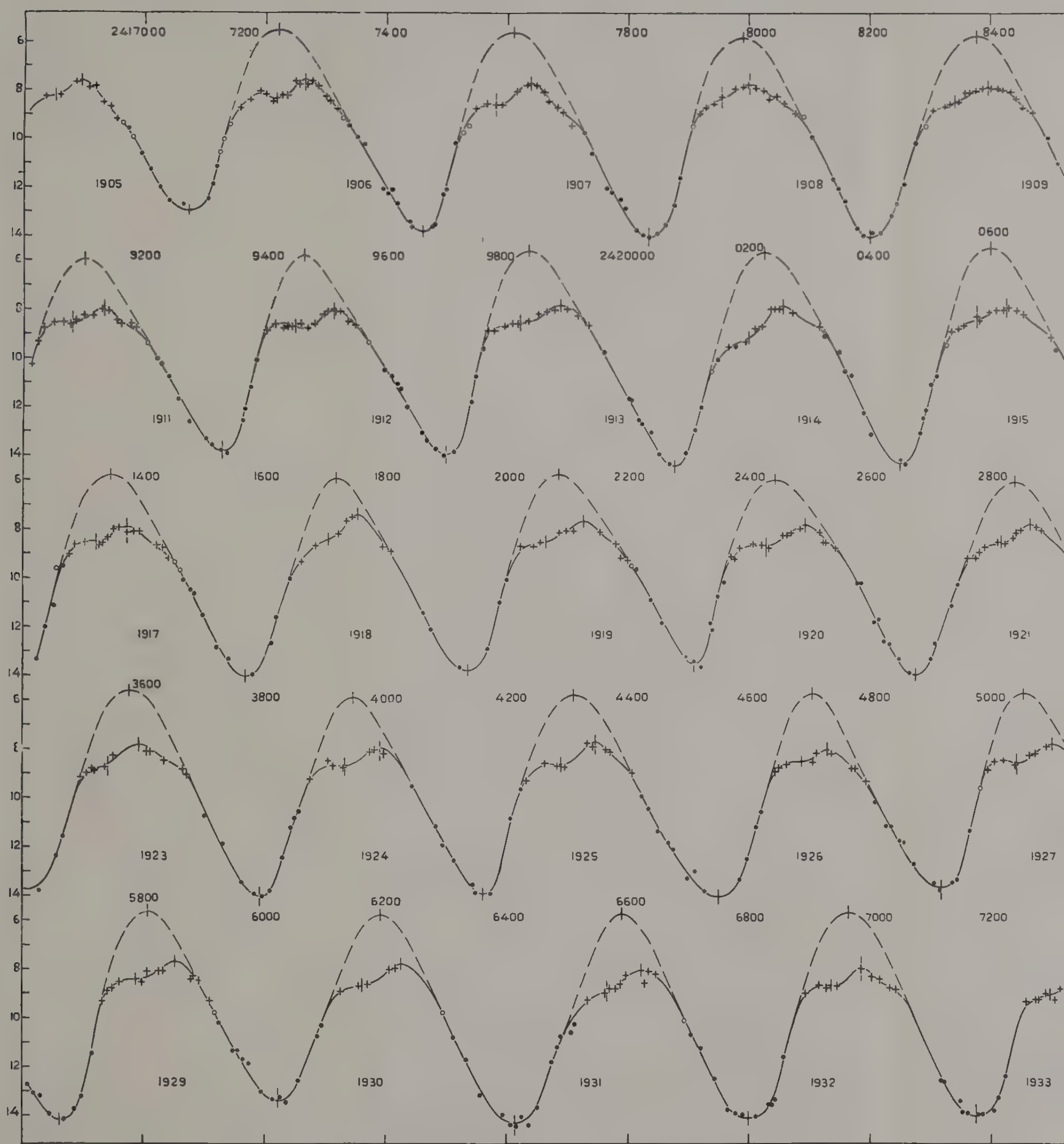
2417000
7200
7400
7800
8000
8200
8400
1905
1906
1907
1908
1909
9200
9400
9600
9800
2420000
0200
0400
0600
1911
1912
1913
1914
1915
1400
1600
1800
2000
2200
2400
2600
2800
1917
1918
1919
1920
1921
3600
3800
4000
4200
4400
4600
4800
5000
1923
1924
1925
1926
1927
5800
6000
6200
6400
6600
6800
7000
7200
1929
1930
1931
1932
1933

Fig. 1.

TABELLE III.

E	Minima m					Maxima M				
	B	v	R	$B-R$	$B-F$	B	v	R	$B-R$	$B-F$
− 14	—	—	—	—	—	^{241}6894	^{m}7.6	6897	− 3	+ 11
− 13	^{241}7074	^{m}13.0	7085	− 11	− 1	7264	7.5^5	7270	− 6	+ 4
− 12	7460	13.8	7458	+ 2	+ 9	7638	7.7	7643	− 5	+ 2
− 11	7833	14.1	7831	+ 2	+ 6	8000	7.8	8016	− 16	− 12
− 10	8199	14.1	8204	− 5	− 4	8395	7.9	8389	+ 6	+ 7
− 9	8581	13.6	8577	+ 4	+ 2^5	8757	7.5	8762	− 5	− 6^5
− 8	8954	13.7^5	8950	+ 4	+ 1	9134	7.9	9135	− 1	− 4
− 7	9328	13.7^5	9323	+ 5	+ 1	9513	7.9^5	9508	+ 5	+ 1
− 6	9698	13.9	9696	+ 2	− 3	9887	7.8^5	9881	+ 6	+ 1
− 5	^{242}0076	14.4^5	0069	+ 7	+ 2	^{242}0255	7.8^5	0254	+ 1	− 4
− 4	0448	14.3^5	0442	+ 6	+ 2	0624	7.9^5	0627	− 3	− 7
− 3	0817	14.0	0815	+ 2	− 1	1000	7.9	1000	0	− 3
− 2	1195	14.1	1188	+ 7	+ 6	1373	7.9	1373	0	− 1
− 1	1567	14.0	1561	+ 6	+ 7	1753	7.4	1746	+ 7	+ 8
0	1935	13.8	1934	+ 1	+ 4	2127	7.6^5	2119	+ 8	+ 11
+ 1	2308	13.5	2307	+ 1	+ 5	2492	7.8	2492	0	+ 4
+ 2	2674	13.9^5	2680	− 6	− 0^5	2863	7.7^5	2865	− 2	+ 3
+ 3	3045	14.0	3053	− 8	− 2	3231	7.7	3238	− 7	− 1
+ 4	3411	13.7	3426	− 15	− 8^5	3593	7.7^5	3611	− 18	− 11^5
+ 5	3792	14.0	3799	− 7	− 1	3989	7.9	3984	+ 5	+ 11
+ 6	4160	13.9	4172	− 12	− 7	4345	7.6^5	4357	− 12	− 7
+ 7	4548	14.0	4545	+ 3	+ 6	4729	7.9^5	4730	− 1	+ 2
+ 8	4917	13.6^5	4918	− 1	0	5100	7.7^5	5103	− 3	− 2
+ 9	5288	13.9^5	5291	− 3	− 5	5466	7.6^5	5476	− 10	− 12
+ 10	5663	14.2	5664	− 1	− 6	5852	7.6^5	5849	+ 3	− 2
+ 11	6022	13.3^5	6037	− 15	− 24	6226	7.7^5	6222	+ 4	− 5
+ 12	6414	14.2^5	6410	+ 4	− 8	6620	8.0	6595	+ 25	+ 13
+ 13	6798	14.1	6783	+ 15	0	6985	7.9	6968	+ 17	+ 2
+ 14	7174	14.0	7156	+ 18	0	—	—	—	—	—
		13.90			± 5		7.77			± 6

Minima m und der Maxima M. Die Spalte R wurde mit den einfachen Elementen:

$$2421934^d + 373^d\,E \quad \text{(für die Minima)}$$

und

$$2422119 + 373\,E \quad \text{(für die Maxima)}$$

gerechnet.

Die übrigbleibenden B—R sind zwar nicht sehr gross, zeigen aber einen Überschuss von Zeichenfolgen; namentlich bei den Minima wird eine wesentliche Verbesserung durch die Hinzuziehung eines graphisch abgeleiteten periodischen Gliedes erzielt, das ich dann auch bei den im Grossen und Ganzen mit den Minima parallel laufenden Maxima anwendete, obwohl hier der Gewinn gering ist.

Die definitiven Elemente F lauten:

$$\left.\begin{array}{l}\text{Minima: } 2421934^d \\ \text{Maxima: } 2422119\end{array}\right\} + 373^d.8\,E + 10^d \sin 15^\circ\,(E + 13).$$

Durch einen Rechenfehler, den ich erst nach Abschluss der Diskussion bemerkte, wurde für das Minimum 6022 ($E = +11$) in der Spalte B—F —6 gefunden, statt —24. Tatsächlich würde jetzt für die Normalepoche der Minima eher 2421933 zu nehmen sein, doch habe ich auf eine Neubearbeitung verzichtet. Die Wahl zwischen den beiden Formeln R und F, und infolgedessen zwischen den Perioden 373^d oder $373^d.8$ ist schwer zu treffen; jedenfalls sind Perioden wie $370^d.4$ oder $370^d.5$, welche die älteren Epochen befriedigend darstellen (*G und L* I, 116), für das hier diskutierte Beobachtungsmaterial unbrauchbar. PRAGER's Katalog für 1933 gibt den wieder zu grossen Periodenwert $376^d.0$, und das aus sämtlichen von mir seit d.J. 1905 in den *Astr. Nachr.* mitgeteilten Epochen der Minima und Maxima abgeleitete allgemeine Mittel ist 374^d.

Die extremen Werte des Lichtwechsels sind:

$$\left.\begin{array}{l}\text{Minimum: } v = 13^m.90 \pm 0^m.057 \\ \text{Maximum: } v = 7.77 \pm 0.029\end{array}\right\} \text{(m.F.)}.$$

Die Amplitude beträgt somit $6^m.13$. Sowohl beim Minimum wie beim Maximum scheinen die Abweichungen vom Mittelwert regellos aufzutreten.

Wie man sieht (Fig. 1) unterliegt jede Aufhellung von *T Camelopardalis* ohne Ausnahme einer Verzögerung, welche in 14 von den 28 Fällen den Charakter eines Stillstandes oder sogar eines sekundären Minimums annimmt. Auch im Abstieg tritt öfters eine Verzögerung auf, bald kaum angedeutet (5 Fälle), bald aber unverkennbar (12 Fälle). Zwecks Bildung einer mittleren Kurve verfuhr ich wieder so wie es früher bei *T Cassiopeiae* beschrieben wurde (Proc. **34**, 220).

Die Tabelle IV A gibt die Epochen der im Aufstieg abgelesenen Wendepunkte, nebst der Vergleichung mit den einfachen Elementen R:

$$2422064^d + 373^d\,E.$$

Obwohl bei 2417953 und 2426565 der Wendepunkt kaum anzugeben war, so stimmten diese Epochen dennoch bei der Bildung der mittleren

TABELLE IV.

E	*A.* Wendepunkte				*B.* Ungestörte Maxima			
	B	v	R	$B-R$	B	v	R	$B-R$
− 14	^{241}6853	$\overset{m}{8.2}$	6842	+ 11	—	—	—	—
− 13	7217	8.3	7215	+ 2	^{241}7220	$\overset{m}{5.5}$	7237	− 17
− 12	7580	8.6	7588	− 8	7610	5.6^5	7610	0
− 11	7953	8.3^5	7961	− 8	7989	5.8	7983	+ 6
− 10	8340	8.6	8334	+ 6	8376	5.8	8356	+ 20
− 9	8701	8.6	8707	− 6	8723	5.5	8729	− 6
− 8	9081	8.5^5	9080	+ 1	9102	6.0	9102	0
− 7	9450	8.7	9453	− 3	9464	5.8	9475	− 11
− 6	9821	8.6	9826	− 5	9835	5.6	9848	− 13
− 5	^{242}0199	9.2	0199	0	^{242}0224	5.7	0221	+ 3
− 4	0576	8.4	0572	+ 4	0598	5.6	0594	+ 4
− 3	0950	8.4^5	0745	+ 5	0978	5.7	0967	+ 11
− 2	1322	8.5	1318	+ 4	1345	5.8	1340	+ 5
− 1	1704	8.4	1691	+ 13	1717	5.9^5	1713	+ 4
0	2063	8.5	2064	− 1	2085	5.8	2086	− 1
+ 1	2427	8.6^5	2437	− 10	2442	6.0	2459	− 17
+ 2	2815	8.6	2810	+ 5	2837	6.1	2832	+ 5
+ 3	3179	8.2	3183	− 4	3207	6.2^5	3205	+ 2
+ 4	3542	8.6	3556	− 14	3576	5.6	3578	− 2
+ 5	3931	8.6	3729	+ 2	3945	5.9	3951	− 6
+ 6	4288	8.5	4302	− 14	4309	5.8	4324	− 15
+ 7	4686	8.5	4675	+ 11	4703	5.9	4697	+ 6
+ 8	5040	8.5	5048	− 8	5052	5.7^5	5070	− 18
+ 9	5409	8.5^5	5421	− 12	5433	5.8	5443	− 10
+ 10	5788	8.4	5794	− 6	5807	5.6	5816	− 9
+ 11	6161	8.6	6167	− 6	6191	5.7	6189	+ 2
+ 12	6565	8.9	6540	+ 25	6588	5.7^5	6562	+ 26
+ 13	7934	8.6	6913	+ 21	6964	5.7	6935	+ 29
+ 14	7295	9.0^5	7286	+ 9	—	—	—	—
		8.56				5.78		

Teilkurven mit. Unberücksichtigt blieb aber die Epoche 2427295, da beim Abschluss der Rechnung der Aufstieg nach dem letzten Minimum noch nicht weit genug vorgeschritten war. Die mittlere Helligkeit im Wendepunkt ist:

$$v = 8^{m}.54 \pm 0.034 \text{ (m.F.)}.$$

Die drei Teilkurven schliessen sich, wie aus der Fig. 2 ersichtlich, auch hier wieder genau an einander an, und liefern zusammen die mittlere Kurve *B* (Tabelle V).

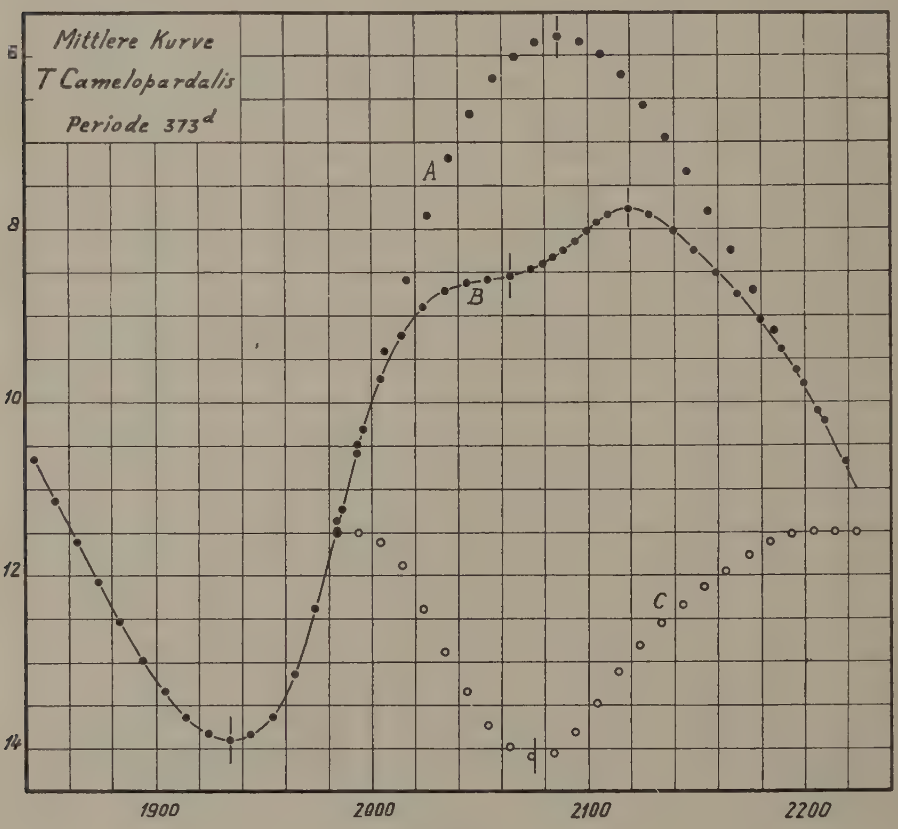

Fig. 2.

Aus dem Kurvenzug liest man für die Normalepoche des Wendepunktes eher 2060 als 2064 ab.

Wird auch bei *T Camelopardalis* in der üblichen Weise die Kurve von der Störung befreit, so entstehen die ungestörten Maxima, welche (Tabelle IV *B*) mit den einfachen Elementen *R*:

$$2422086^{d} + 373^{d} E$$

verglichen wurden.

Die Teilkurve *A* der ungestörten Maxima (s. Fig. 2) schliesst sich der-

TABELLE V. Die mittlere Kurve.

Phase	v	Phase	v	Phase	v	Phase	v	Phase	v
d	m	d	m	d	m	d	m	d	m
−90	10.61	−10	13.83	+70	9.73	+150	8.33	+230	8.61
−80	11.10	0	13.90	+80	9.22	+160	8.14	+240	8.88
−70	11.59	+10	13.83	+90	8.90	+170	7.93	+250	9.20
−60	12.06	+20	13.63	+100	8.71	+180	7.78	+260	9.58
−50	12.52	+30	13.13	+110	8.62	+190	7.79	+270	10.02
−40	12.95	+40	12.38	+120	8 58	+200	7.90	+280	10 48
−30	13.33	+50	11.44	+130	8.54	+210	8.11	+290	10.96
−20	13.64	+60	10.50	+140	8.46	+220	8.35		

jenigen der Minima vollständig an. Für die Schiefe der ungestörten Kurve findet man

$$\frac{M-m}{p} = 0.407\,.$$

Die maximale „ungestörte" Helligkeit ist:

$$v = 5^{\mathrm{m}}.78 \pm 0^{\mathrm{m}}.033 \ \text{(m.F.)}.$$

Schliesslich wurde die Differenzkurve A—B gebildet, welche sich diesmal bestimmt asymmetrisch gestaltet: der Aufstieg vollzieht sich langsamer als der Abstieg. Das Minimum, zu $2^{\mathrm{m}}.60$, fällt auf 2422075, also 11 Tage vor dem ungestörten Maximum; der Veränderliche erleidet beim Aufstieg eine Verfinsterung, welche ihn von 91 % seines Lichtes beraubt.

Zusammenfassung.

Aus 653 in den Jahren 1905 bis 1933 (2416835 bis 2427332) angestellten Beobachtungen von *T Camelopardalis* sind die folgenden Elemente des Lichtwechsels abgeleitet worden:

$$\left.\begin{array}{ll}\text{Minimum:} & 2421934^{\mathrm{d}}\\ \text{Maximum:} & 2422119\end{array}\right\} + 373^{\mathrm{d}}.8\,E + 10^{\mathrm{d}}\,sin\,15^{\circ}\,(E+13)\,; \quad \begin{array}{r} v = 13^{\mathrm{m}}.90\\ v = 7.77\\ \hline \end{array}$$

$$\text{Amplitude} \;=\; 6.13.$$

Der Stern scheint beim Aufstieg eine Verdunkelung von $2^{\mathrm{m}}.60$ zu erleiden, welche einen asymmetrischen Verlauf hat, und deren Minimum auf 2422075 fällt.

Utrecht, September 1933.

Embryology. — *Ueber die chemischen Prozesse bei der embryonalen Induktion.* Von M. W. WOERDEMAN.

(Communicated at the meeting of September 30, 1933).

In einigen Mitteilungen habe ich die Ergebnisse histiochemischer Untersuchungen veröffentlicht, die zeigten, dasz sich in den Zellen embryonaler Organisatoren von Amphibienkeimen glykolytische Prozesse abspielen. Es wurde vermutet, dasz diese Prozesse mit der Induktionswirkung zusammenhängen.

So wurde die von mir bei Axolotlkeimen in der dorsalen Urmundlippe und in der Augenblase gefundene Glykolyse mit der Induktion der Neuralplatte und der Linsenanlage in Zusammenhang gebracht.

Nun hat nachher in meinem Institute Herr Dr. CHR. P. RAVEN einige Experimente ausgeführt, die eine weitere Stütze für die obengenannte Hypothese liefern. Es zeigte sich, dasz präsumptive Epidermis, die in das Gebiet der dorsalen Urmundlippe transplantiert und bei den Gastrulationsbewegungen mit-invaginiert wurde, ebenso wie die invaginierten Zellen der Chorda-Mesodermanlage in der dorsalen Urmundlippe ihr Glykogen zum grössten Teile verliert. Wenn nun die präsumptive Epidermis an Ort und Stelle geblieben wäre, so hätte sie nicht so schnell und ausgiebig ihr Glykogen verloren. Die neue Umgebung führt also zu einem veränderten Stoffwechsel, der sich histiochemisch durch die Glykolyse nachweisen lässt. Da bekanntlich die präsumptiven Epidermiszellen, wenn sie auf experimentellem Wege in das Urdarmdach geraten, in der neuen Umgebung Induktionsvermögen erhalten und nach Einstecken in das Blastocöl eines anderen Keimes die Bildung einer Neuralplatte induzieren, so liegt es nahe die neu erworbene Eigenschaft den veränderten Stoffwechselprozessen in der transplantierten Epidermis zuzuschreiben. Eine kausale Verknüpfung ist wohl sehr wahrscheinlich.

In einer zweiten Versuchsreihe hat RAVEN die glykolytischen Prozesse untersucht in Stückchen Neuralplatte, die als Organisatoren in das Blastocöl anderer Keime eingesteckt wurden.

Kontroll-Wahrnehmungen zeigten den Glykogengehalt der Neuralplatte des Spenderkeimes im Momente der Entnahme von als Organisatoren verwandten Stückchen. Auch wurden Spenderkeime weiter gezüchtet und zu gleicher Zeit mit den Wirtskeimen fixiert, wonach der Glykogengehalt des Neuralrohres untersucht wurde.

In den Wirtskeimen üben bekanntlich die Stückchen Neuralplatte Induktionswirkung aus und es werden Neuralplatten induziert.

Wenn man nun die Wirtskeime, wobei Induktion sichtbar ist, mikro-

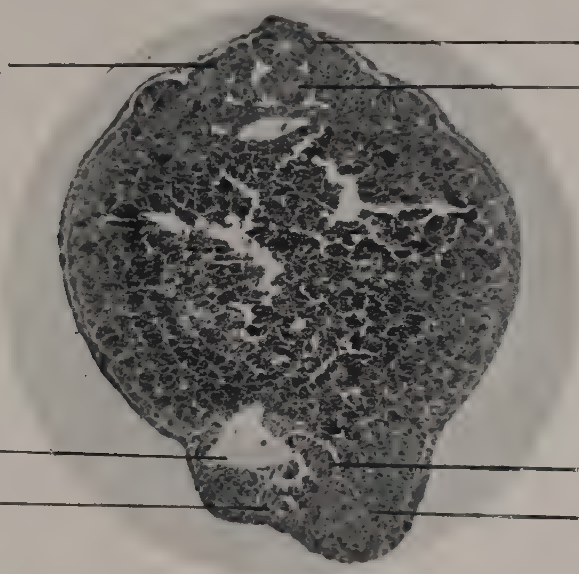

Abb. 1. Induktion durch menschliches Muskelgewebe bei einem Axolotl-keim, (Querschnitt).

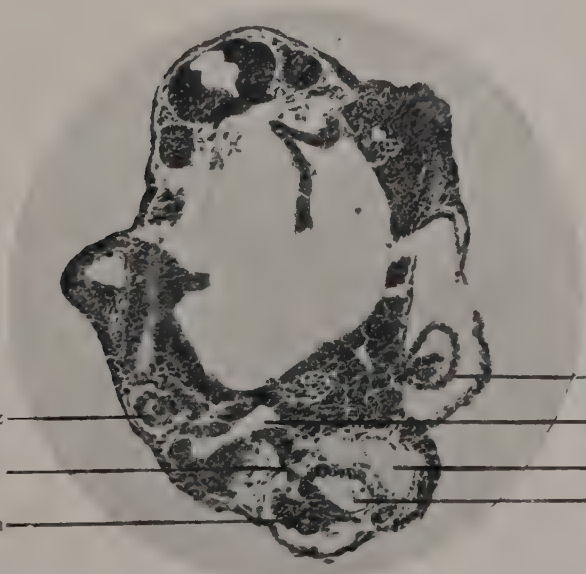

Abb. 2. Sekundäre Embryonalanlage (Axolotl) durch Muskelgewebe induziert.

skopisch untersucht, so stellt sich heraus, dasz die Induktoren deutlich weniger Glykogen enthalten als die Kontroll-Neuralplatten und Neuralröhre. Durch Implantation in das Blastocöl haben die Implantate offenbar ihr Glykogen mehr oder weniger vollständig verloren, jedenfalls zeigen sie einen mit starker Glykolyse einhergehenden Stoffwechsel und es liegt wiederum nahe ihre Induktionswirkung mit diesen Stoffwechselprozessen verknüpft zu denken.

So haben wir jetzt also wahrgenommen, dasz Glykolyse auftritt in Zellgruppen, die bei der normalen Entwicklung als Organisatoren betrachtet werden können, und auch in Zellgruppen, die normalerweise keine so deutliche Glykolyse aufweisen, wenn sie nur auf experimentellem Wege zu Organisatoren gemacht werden.

Inzwischen wurde auch untersucht, ob Gewebe, die einen Stoffwechsel besitzen, der durch starke Glykolyse gekennzeichnet ist, Induktionswirkung haben würden.

Schon habe ich mitgeteilt, dasz es meinem Schüler, Herrn Cand. med. J. F. Hampe, gelungen war bei Axolotlkeimen die Induktion von Neuralplatten zu beobachten nach Implantation von Rattenkrebsgewebe in das Blastocöl junger Gastrulae. Auch mit Hühnersarkom (Peyton-Rous) erhielt er positive Resultate.

Die Versuche sind seitdem von Hampe weiter fortgesetzt und es hat sich herausgestellt, dasz auch menschliches Karzinomgewebe (Adenokarzinom der Mamma) eine Induktionswirkung besitzt.

Auffallend starke Induktionswirkung besitzt aber auch quergestreiftes Muskelgewebe des Menschen.

Dabei fand nicht nur die Induktion von Neuralplatten statt, sondern es bildeten sich mehr oder weniger vollständige Embryonalanlagen. So induzierten kleine Stückchen eines Muskels beim Wirt im Gebiet des Herzens ein Neuralrohr mit Chorda, Myotomen (allerdings nicht regelmässig geordnet und manchmal unter der Chorda zu einer unregelmässigen Muskelmasse verwachsen) und einen kleinen Darm und ein Herzchen.

Ein wenig kranial von der Analöffnung fand Hampe bei einem anderen Versuchskeim eine induzierte Schwanzanlage mit Neuralrohr, Chorda, Myotomen, usw.

Es hat nicht nur das Ektoderm auf die Induktionswirkung des Muskelstückchens reagiert mit der Bildung von Neuralplatte, sondern es ist bei der Untersuchung der erwähnten Fälle wohl sehr wahrscheinlich geworden, dasz auch das Mesoderm mit der Bildung von Chorda und Myotomen reagieren kann.

In Abb. 1 sieht man ventral vom Wirtsdarm das implantierte Muskelgewebe. Daneben liegt ein Zellstrang, der deutlich bei starker Vergrösserung den Bau einer Chorda zeigt. Ein (undeutliches) Neuralrohr ist vorhanden, während weiter die genannten sekundären Organe durch eine Mesodermmasse ohne deutliche Struktur umgeben sind.

Abb. 2 zeigt den oben schon beschriebenen Fall. In der Herzgegend des

Wirtes liegt hier neben dem Muskel-Implantate ein Neuralrohr mit Chorda, Myotomen und einem Darm. Auch eine kleine Herzanlage ist anwesend.

Die dritte Abbildung zeigt einen Abschnitt der Abb. 2 mit starker Vergrösserung. Auffallend ist in dieser Abbildung (und in den Präparaten findet man das regelmässig zurück), dasz das implantierte Muskelgewebe Zeichen von Histiolysis zeigt. In den meisten Muskelimplantaten ist wohl die Faserstruktur erhalten, die Kerne dagegen fehlen meistens.

Mit Geschwulstgewebe und Muskelgewebe, die durch ihre starke Glykolyse (obwohl nicht in beiden Geweben auf derselben Weise verlaufend) charakterisiert sind, bekommt man also schöne Induktionen.

Nun finden aber in Geschwulstgewebe, Muskelgewebe, embryonalen Zellgruppen, die Induktionswirkung zeigen, natürlich nicht nur glykolytische Prozesse statt und es besteht die Möglichkeit, dasz die Induktionswirkung nicht oder nicht ausschliesslich von der Glykolyse abhängig sei. Es lag also auf der Hand um zu versuchen ein Experimentum crucis auszuführen, was ich auf der folgenden Weise machte.

Ich ging von der Ueberlegung aus, dasz man offenbar mit einem Einflusz der Blastocölflüssigkeit auf die glykolytischen Prozesse der Induktoren zu rechnen hat. Bei der Gastrulation verschwindet nämlich diese Flüssigkeit und es tritt eine neue Höhle (das Gastrocöl) auf, die auch mit Flüssigkeit gefüllt ist. Wie der Blastocölinhalt verschwindet und wie die Gastrocölflüssigkeit entsteht, ist, so weit mir bekannt, noch nicht endgültig festgestellt. Ich vermute, dasz die Blastocölflüssigkeit in irgend einer Weise in das Gastrocöl zurecht kommt, wobei sie vielleicht das Urdarmdach passiert. Es wäre dann denkbar, dasz sie dabei die Stoffwechselprozesse dieses Daches beeinflusst. Es kann doch nicht ohne Bedeutung sein, dasz die Blastocölflüssigkeit ein so hohes p_H besitzt (8, 4—9, 0), wie ich in Zusammenarbeit mit Buytendijk gefunden habe. Das muss wohl auf eine Rolle im chemischen Geschehen bei der Entwicklung hinweisen. Es ist auch bemerkenswert, dasz Stückchen Neuralplatte im Blastocöl Glykogen verlieren, und dasz präsumptive Epidermis im Urdarmdach dieselbe Erscheinung zeigt. Obwohl allerhand andere Erklärungsmöglichkeiten bestehen, habe ich doch an erster Stelle an einen Einfluss der Blastocölflüssigkeit gedacht. Ich habe auch versucht, ob aus der Blastula mit einer Mikropipette entfernte Blastocölflüssigkeit glykolytische Eigenschaften besitze und habe den vorläufigen Eindruck gewonnen, dasz sie eine solche Wirkung tatsächlich besitzt. Diese Frage wird aber jetzt in meinem Institute noch ausführlicher untersucht.

Ausgehend von der Vermutung, dasz die Flüssigkeit im Blastocöl die Glykolyse fördern oder hervorrufen kann, ist auch die Wahrnehmung von Holtfreter leicht verständlich, dasz abgetötete, ins Blastocöl gesteckte, Nicht-Organisatoren, eine Induktionswirkung zeigen, während sie in lebendem Zustande keine solche Wirkung besitzen. Es ist nämlich möglich, dasz die Blastocölflüssigkeit im toten Gewebe glykolytische Prozesse in Gang setzt, aber nicht im lebenden, weil bestimmte lebende Geweben oder

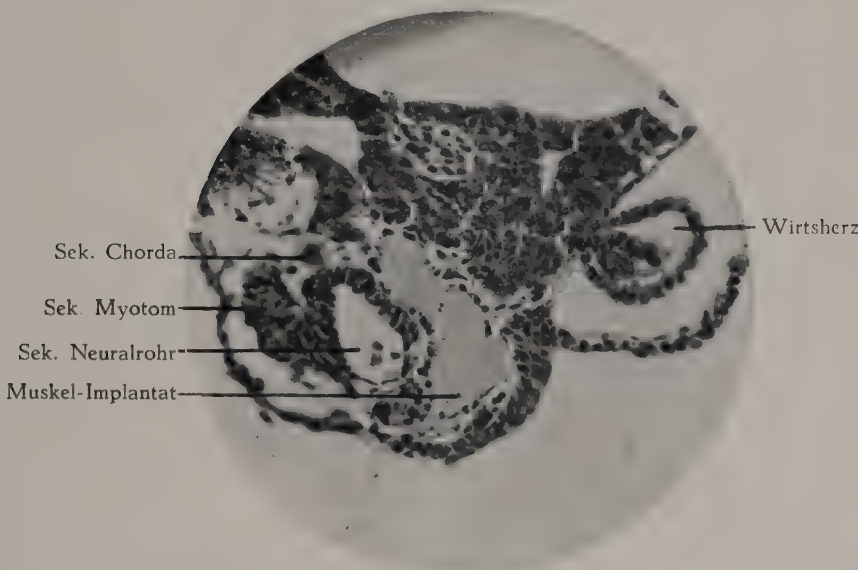

Abb. 3. Teil der Abb. 2 mit stärkerer Vergrösserung.

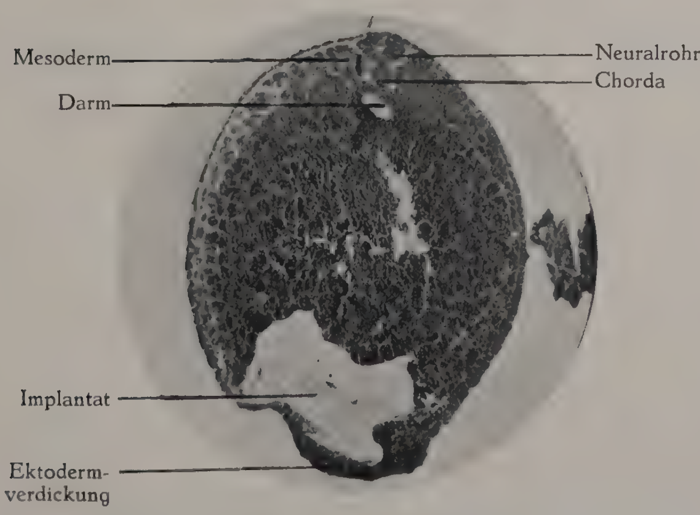

Abb. 4. Ektodermverdickung bei einem Axolotlkeim durch Implantation glykogenhaltiger Gelatingallerte erhalten.

embryonale Zellen für ihre Wirkung in irgend einer Weise unempfindlich sind.

Es steht also Nichts der Hypothese im Wege, dasz die Blastocölflüssigkeit im Stande ist glykolytische Prozesse in Gang zu setzen oder zu fördern und das war der Ausgangspunkt des folgenden Versuches.

In einer Gelatin-gallerte wurde Glykogen gelöst. Kleine Würfelchen dieser Gallerte wurden in das Blastocöl von Axolotlkeimen hineingesteckt. Auch wurden zur Kontrolle ähnliche Versuche gemacht mit reiner Gallerte, also ohne Glykogen.

In einigen Fällen war die Gastrulation durch die Schwellung der Implantate ziemlich stark gestört. Aber daneben habe ich in manchen Fällen eine normale Entwicklung gesehen. Wenn nun die Stückchen der Glykogen-Gallerte bei der Gastrulation unter das Ektoderm zu liegen kamen, reagierte es mit dem Auftreten stark pigmentierter Verdickungen, die äusserlich mit Neuralplatten sehr viel Ähnlichkeit besassen. Aber bei mikroskopischer Untersuchung zeigten sie nicht den typischen Bau von Neuralplatten. Lag das Implantat im Entoderm, so fehlte jede Reaktion, lag es aber in der Nähe von Mesoderm, so reagierte das Mesoderm, ebenso wie das Ektoderm, mit einer starken Wucherung, die aber keine typische Struktur aufwies. Glykogenfreie Gallert-Implantate haben keine oder nur geringe Zellwucherung zur Folge gehabt. In Abb. 4 sieht man die Ektodermverdickung, die durch eine glykogenhaltige Gelatingallerte in der Bauchgegend des Wirtes induziert wurde, während Abb. 5 das verdickte Ektoderm mit starker Vergrösserung zeigt. Nach meiner Meinung darf man hier nicht von Neuralplattenbildung reden.

Abb. 6 zeigt eine ähnliche Verdickung, die vielleicht noch eher den Gedanken an eine Neuralplatte aufkommen lässt. Sie ist von einer starken Wucherung des Mesoderms begleitet.

Schliesslich sieht man in Abb. 7, wie eine solche Wucherung von Ekto- und Mesoderm äusserlich aussieht.

Nach diesen vorläufigen Versuchen war es meine Absicht durch Veränderung des Glykogengehaltes der Gallerte, durch Festlegung des p_H durch Pufferlösungen usw. zu versuchen, ob nicht die Induktion von deutlichen Neuralplatten möglich wäre. Aber gerade beim Anfang dieser Versuchsreihe erschien in den „Naturwissenschaften" vom 7. Juli dieses Jahres eine Mitteilung von SPEMANN, WEHMEIER und FISCHER, woraus hervorging, dasz die genannten Untersucher dasselbe Thema bearbeitet hatten.

Sie haben Material, das Induktionswirkung besitzt, auf verschiedenen Weisen behandelt, so z.B. mit Azeton, Alkohol, Aether, Eisessig, trockener Hitze, und haben aus dem Material hergestellte Extrakte auf ihre Induktionsfähigkeit untersucht. Die Untersuchungen führten zu der Auffassung, dasz diese Fähigkeit an einem bestimmten „Induktionsstoff" gebunden sei, aber dasz es daneben auch „Hemmungsstoffe" gibt in den nicht-induzierenden Keimteilen. Aus den beschriebenen Ergebnissen lässt sich noch nicht entscheiden, welcher Natur der Induktionsstoff sei.

Aber in demselben Heft der genannten Zeitschrift findet man einen Nachtrag zu der oben erwähnten Mitteilung, der von FISCHER und WEHMEIER unterzeichnet ist und worin mitgeteilt wird, dasz weitere Untersuchungen der Eigenschaften des „Induktionsstoffes" zur Vermutung geführt haben, dasz er mit Glykogen identisch sei. Keine der bisher bekannten Eigenschaften soll dagegen sprechen.

Auf welchen Untersuchungen diese Vermutung beruht, wird in dem kurzen Nachtrag nicht mitgeteilt und man darf mit Spannung ausführlichere Mitteilungen hierüber entgegensehen.

Was mir aber am meisten interessierte, ist die Mitteilung, dasz es FISCHER und WEHMEIER gelungen sein soll mit Implantaten aus Gelatingallerte, der Glykogen zugesetzt worden war, regelmässig Bildung von Neuralplatten hervorzurufen, während Implantation reiner Gelatine wirkungslos sein soll.

Abbildungen fehlen selbstverständlich in dem kurzen Nachtrag und vorläufig lässt sich also nicht beurteilen, ob wirkliche Neuralplatten gebildet sind. Wie ich schon mitteilte, ist es mir, der gleichzeitig mit FISCHER und WEHMEIER Versuche mit glykogenhaltiger Gelatingallerte ausgeführt habe, nicht gelungen mikroskopisch unzweifelbar Neuralplatten zu finden. Wohl machten die Ektodermwucherungen äusserlich durch ihre Pigmentierung den Eindruck von kleinen Neuralplatten.

Wenn tatsächlich die Freiburger Autoren Neuralplattenbildung erhalten haben, so musz noch untersucht werden, welchem glücklichen Zufall sie diesen schönen Erfolg verdanken, denn, wie wir gesehen haben, ist in meinen Versuchen Neuralplattenbildung nicht unzweifelbar festzustellen gewesen. Haben sie vielleicht die richtige Konzentration des Glykogens getroffen, die richtige Tierart (vermutlich haben sie Triton benutzt, während ich mit Axolotl arbeitete), das richtige p_H der Gallerte, oder haben sie eine andere Gelatine verwendet oder ein anderes Glykogen?

Es ist nicht ohne Bedeutung das zu untersuchen, denn offenbar kommen Nebenfaktoren für den guten Erfolg des Versuches in Frage.

Auch wird man noch nachzuforschen haben, wodurch es verursacht wird, dasz der Induktionsstoff nach SPEMANN, FISCHER und WEHMEIER in Agar und in Gelatine sehr langsam oder gar nicht diffundiert, sodasz Induktormaterial, aufgenommen in möglichst wenig Gelatine, keine Induktionswirkung zeigte, während Glykogen in Gelatine wohl eine Wirkung besitzt.

Die ausführliche Publikation der Versuche von FISCHER und WEHMEIER muss man jetzt abwarten.

Es hat mich sehr gefreut, dasz durch die Untersuchungen aus dem Institute von SPEMANN meine Hypothese, dasz das Glykogen eine Rolle spielt bei der embryonalen Induktion, bestätigt wurde.

Nur habe ich Bedenken dagegen, dasz FISCHER und WEHMEIER von Glykogen als „Induktionsstoff" sprechen. Immer habe ich betont, dasz in den Induktoren glykolytische Prozesse auftreten, dasz also Glykogen verschwindet. Das Urdarmdach, das doch bekanntlich die Neuralplatte

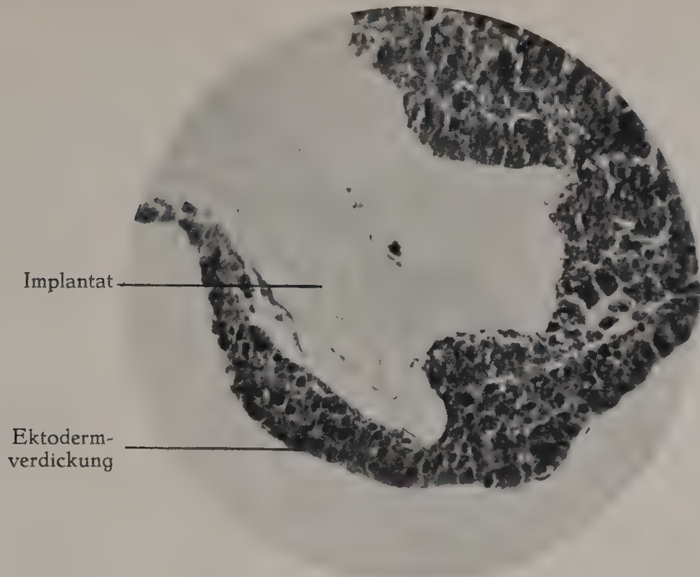

Abb. 5. Teil der Abb. 4 bei stärkerer Vergrösserung.

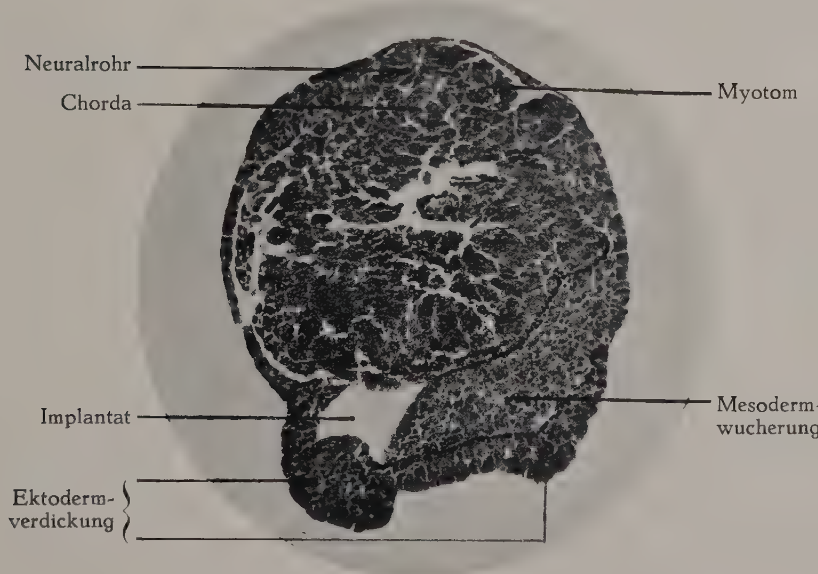

Abb. 6. Ektodermverdickung und Mesodermwucherung bei einem Axolotlkeim durch Implantation glykogenhaltiger Gelatingallerte hervorgerufen.

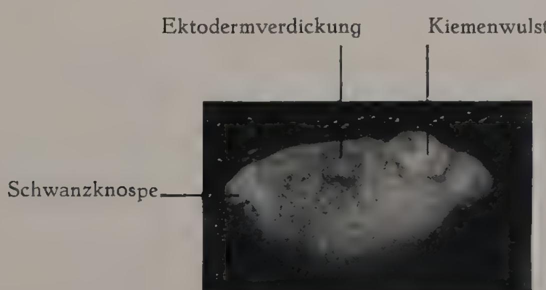

Abb. 7. Pigmentierte Ektodermverdickung bei einem Axolotlkeim durch

induziert, ist glykogenarm. Glykogen als solches kann m.E. nicht der „Induktionsstoff" sein. Ich habe vom Anfang an gemeint, dasz die Stoffwechselprozesse in den Organisatoren (die natürlich sehr kompliziert sind und von denen nur die Glykolyse leicht histiochemisch nachweisbar ist) als Ursache der Induktionswirkung in Betracht kommen. Ich habe dabei noch unentschieden lassen müssen, ob wirklich ein bestimmter chemischer Stoff die Induktion verursacht. Es kommen noch so viele andere Möglichkeiten in Betracht.

Es mag sein, dasz die Induktionswirkung auf Strahlung beruht, oder auf die Veränderung des p_H, wodurch die Permeabilität und die osmotischen Verhältnisse geändert werden oder bestimmte Enzyme aktiviert, während die Wirkung anderer Fermente unterdrückt wird. Das veränderte p_H kann auch den kolloidalen Zustand des Protoplasmas veränderen usw. Das Alles kann natürlich auf die Entstehung eines bestimmten Stoffes beruhen, kann aber auch eine Begleiterscheinung verschiedener chemischer Prozesse sein.

Eine Entscheidung ist hier noch nicht möglich und vorläufig ist m.E. nur bewiesen, dasz in den Induktoren merkwürdige Stoffwechselprozesse vor sich gehen, wovon die Glykolyse nachgewiesen wurde und die offenbar die Bedingungen für die Induktionswirkung abgeben.

Ob auch andere, nicht mit Glykolyse verläufende, Prozesse Induktionswirkungen verursachen, soll noch untersucht werden.

Obwohl nun FISCHER und WEHMEIER von Glykogen als „Induktionsstoff" sprechen und offenbar dadurch veranlasst wurden Versuche mit Gelatingallerte, der Glykogen zugesetzt war, zu beginnen, wird in dem genannten Nachtrag aber auch die Vermutung geäussert, dasz die Wirkung des glykogenhaltigen Implantates auf das überlagernde Ektoderm durch eine an der Berührungsfläche stattfindende Glykolyse zustande kommt.

Auch wird die Induktionsfähigkeit bestimmter Keimbezirke entweder mit ihrem Glykogengehalt oder wahrscheinlicher mit Besonderheiten ihres Glykogenstoffwechsels (mit erhöhter Glykolyse) in Zusammenhang gebracht. Mit der zuletzt genannten Auffassung kann ich mich besser einverstanden erklären. Die Verfasser kommen damit zu derselben Hypothese, die ich schon einige Monate früher in einigen Mitteilungen in diesen Proceedings publiziert hatte, und von der wir bei unseren Untersuchungen ausgegangen sind. Leider ist sie ihnen unbekannt geblieben.

Inzwischen ist nun auch von englischer Seite die Frage nach dem Induktionsfaktor in Angriff genommen worden. WADDINGTON, JOSEPH und DOROTHY M. NEEDHAM haben in Nature (12 August 1933) die Ergebnisse ihrer Untersuchungen publiziert, die hierauf hinausgehen, dasz auch sie mit Organisatorextrakten die Induktion von Neuralröhren (oder meistens von nicht organisierten, aber doch histiologisch als Neuralgewebe erkennbaren Zellmassen) erhalten haben. Sie meinen, dasz namentlich Aether- oder Petroläther-Extrakte den wirksamen Substanz enthalten.

Diese Wahrnehmung ist nicht vereinbar mit der Auffassung, dasz Glykogen als solches der Induktionsstoff sei.

Es kommt mir aber nicht unwahrscheinlich vor, dasz unter den Abbauprodukten des Glykogens, die sich wohl mit anderen Zellkomponenten verbinden werden, auch ätherlösliche Produkte vorkommen.

Es braucht also die Wahrnehmung der englischen Forscher nicht der Vorstellung zu wiedersprechen, dasz glykolytische Prozesse die Faktoren (oder den Faktor) der Induktion liefern.

Fortgesetzte Untersuchungen der Entwicklungsmechaniker in Zusammenarbeit mit den Biochemikern werden hoffentlich bald die wahre Natur der Induktionswirkung enträtselen.

Zum Schluss muss ich noch sehr kurz eingehen auf eine Frage allgemeiner Bedeutung.

Mit sehr verschiedenen Induktoren hat man die Bildung von Neuralplatten und Embryonalanlagen hervorrufen können. (Mir sind noch nicht die Details bekannt von HOLTFRETER's Versuchen, mitgeteilt auf dem Zytologenkongress in August dieses Jahres in Cambridge, der nach mündlicher Mitteilung eines Besuchers dieses Kongresses mit sehr verschiedenen Vertebraten- und Evertebratengeweben Induktion bei Amphibienkeimen hervorrufen konnte) [1]).

So hat z.B. UMAŃSKI mit Regeneratgewebe Induktion erhalten. OKUNEFF zeigte, dasz sich im Regenerate eine intensive Glykolyse abspielt. Nebenbei sei mitgeteilt, dasz auch in meinem Institute mit Regeneratgewebe Induktionen erhalten wurden (HAMPE). Es wurde der Regenerationskegel einer amputierten Unkenpfote exstirpiert und kleine Stückchen dieses Materiales in das Blastocöl von Axolotlkeimen implantiert, wonach in einigen Fällen Induktion auftrat.

Bis jetzt haben alle mit Erfolg benutzten Induktoren gemeinsam ihren hohen Glykogengehalt und die glykolytischen Stoffwechselprozesse.

Nur in zwei Mitteilungen fand ich Induktion erwähnt von Neuralplatten durch lokale Temperaturerhöhung des Ektoderms bei Amphibienkeimen (GILCHRIST und CASTELNUOVO).

Wenn es tatsächlich möglich ist durch Einführung von Temperaturgradienten die Induktion von Neuralplatten zu erhalten, dann ist es sehr wahrscheinlich, dasz die Induktionswirkung auf eine lokale Veränderung des Stoffwechsels der Ektodermzellen beruhe.

Man wird dann zu der Vorstellung geführt, dasz bei der normalen Entwicklung dasjenige, was eine noch nicht endgültig determinierte Zellgruppe werden soll, abhängt von der Weise, in der ihre Umgebung ihren Stoffwechsel beeinflusst. Der Induktor hätte dann als Aufgabe durch seinen eigenen Stoffwechsel die physikalischen und chemischen Milieuveränderungen hervorzurufen, wodurch die physicochemischen Differenzierungen des Reaktionssystems in eine gewisse Richtung gelenkt werden.

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1) *Anmerkung bei der Korrektur*: Sie sind inzwischen publiziert in: Naturwiss. **21**, H. 43, 1933.

Es wird von der grössten Bedeutung sein die Stoffwechselprozesse in Organisatoren und den auf ihre Wirkung reagierenden Reaktionssystemen genau zu untersuchen.

Erst auf diese Weise können wir hoffen in der Induktionsfrage der Lösung näher zu kommen.

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Anthropology. — *Bloodgroup Investigation in the "Hoeksche Waard".* By FLORIS HERS, M. A. VAN HERWERDEN and TH. J. BOELE—NIJLAND. (Communicated by Prof. J. BOEKE.)

(Communicated at the meeting of September 30, 1933).

In the Proceedings Vol. 33, N°. 6, 1930 and Vol. 35, N°. 5, 1932 the first results have been published of the bloodgroup investigation in Holland instigated by the Anthropological Commission of the Royal Academy of Sciences. In the first-mentioned paper relating to 3085 students the technique has been described in detail. It will be sufficient to repeat that all agglutination tests have been performed in duplicate by the same trained investigators. The data were copied on individual cards for each person tested.

The paper published in 1932 contains the results of an investigation in the "Over Veluwe" a part of the province of Gelderland. This time we are able to consider another rural part of the Netherlands, namely the "Hoeksche Waard" one of the islands belonging to the southern part of the province of Zuid-Holland. The first-mentioned author, physician in the small town of Puttershoek collected the bulk of the material and furnished the anthropological data. Both the other authors are responsible for the

agglutination tests and for the selecting of the material, the computations etc.

As to the development of the Hoeksche Waard it may be stated that the different islands forming the southern part of the province of Zuid-Holland are deposits of the delta of the river Maas. To the formation of the Hoeksche Waard however the estuary of the Schelde river has also contributed. In former times a large estuary, called the Striene, joining the Maas and Schelde, separated what later became the Hoeksche Waard into two parts. Before the polders Zuid-Hollandsche and Tijsseler Waard were inundated (the so called St. Elisabethflood of the year 1421) the entire territory consisted of a number of small islands. From the detailed investigation of J. C. RAMAER in the Proceedings of the Academy of Sciences [1]) it may be concluded that in mediaeval times the habited world in that territory terminated in a levee stretching from Dordrecht to Puttershoek, continuing in a levee in the Maas river (actually the town of Maasdam) and from there to Strijen and Geertruidenberg. On the westside of this levee the situation was as it is nowadays in the Biesbosch, namely muddy water courses and marshes, a country only visited in those times by a wandering, hunting, fishing population. Only the Anthoniepolder and a small polder called the W,ale existed before the inundation, the former one since 1355. It was only a long time after the St. Elisabethflood and after the above-mentioned Striene was silted up, that the entire Hoeksche Waard has been consolidated into one island. It seems that the eastern and the western part of the Hoeksche Waard each of them retained their own population and that even today marriages between the inhabitants of different places are infrequent. The people living in Puttershoek, Maasdam. Strijen and 's Gravendeel have to be considered as the descendants of the survivors of the population of the above-mentioned old Zuid-Hollandsche Waard (mentioned for the first time in the year 1200), which was completely inundated in 1421. Except for a number of later immigrants, the population of these places must be considered as descending from the inhabitants of the boroughs swallowed up by the flood.

In treating the anthropological material we had reasons to divide it into several parts, these parts being considered together as well as separately. To begin with we will take the results obtained in the Hoeksche Waard as a whole. It has to be taken into account that the material at our disposal has been dependent on many factors [2]) and that there has been no lack of interest on our side, if we have not succeeded in getting a sufficient number of tests in places which it would have been very desirable to include in the investigation. As to the division made, we have taken the small town of Puttershoek separately, partly because the first author in his position as a

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[1]) J. C. RAMAER. Graphische geschiedenis van Holland bezuiden de Lek en de Nieuwe Maas. Verh. K. Acad. v. Wetenschappen, 1899, II, No. 3.

[2]) Psychological factors playing a considerable role. It is very difficult to obtain a few drops of blood for scientific investigations from our Dutch peasants. It is also extremely difficult to obtain the collaboration of our Dutch colleagues.

physician in this place had the best opportunity of obtaining material there, but principally because the percentage of bloodgroup B in that town shows a considerable difference from that in the surrounding districts and the same holds true for another anthropological trait, the colour of the hair. Only in the few last years has the population of Puttershoek begun to show a certain mobility (emigration to Rotterdam, immigration from the province Noord-Brabant to the sugar factories, immigration from the province of Zeeland to replace the labourers emigrating to Rotterdam). From the election lists of Puttershoek it can be seen that many natives of Puttershoek bear the same family name (often without acknowledging any relationship). Out of 617 electors not less than 99 identical names have been counted. Identical names are also frequentily found amongst the 526 persons collected at random in Puttershoek for the bloodgroup investigation. Only 162 different names have been counted. Even if we consider the whole material collected by the first author in the Hoeksche Waard, the names are reduced to a relatively small number. This material amounts to 1282 persons but the number of family names does not exceed 295. A number of these names already occur in the oldest churchregisters. Puttershoek from olden times is a place where intermarriage has been of frequent occurrence. This explains to a great extent (as will be stated further on) why a population, descending as a whole from a relative small group of people surviving an inundation, shows in its different branches such a difference in bloodgroup relations and (as the first author stated during his investigation) also in general habitus and frequency of diseases.

The eastern part of the Hoeksche Waard (except Puttershoek) has been considered separately. The districts investigated there ('s Gravendeel, Maasdam, Strijen, Strijen Sas) were drained at a later period, namely in the latter half of the 16th century. The town of Oud-Beyerland situated in the western part of the Hoeksche Waard has been taken separately, this small town being inhabited for the greater part by immigrants from the Zuid-Holland towns of Vlaardingen and Schiedam (according to Mr. TRESLING, who has made an exhaustive study of this town). The material in this place has been collected by Dr. A. A. DE KONING as a medical student. A number of places in the middle part of the Hoeksche Waard have been taken together excepted Numansdorp, which has its own history, being situated in the sands which silted up the old Striene. We did not succeed in completing the material collected in that place by Dr. C. FLOHIL.

The material can be classified in another way, namely by taking the boroughs poldered before the 16th century and those after that time. The results of the different divisions made will be found in the text.

As to the neighbouring islands of Putten and Voorne situated in the west of the Hoeksche Waard, after due selection of the material collected there by some medical students, only 252 tests could be considered.

The distribution as to the bloodgroups is as follows:

I. Material collected by the first author:

Number	O	A	B	AB
1282	569	590	97	26
	44.4 %	46.0 %	7.6 %	2.0 %
	± 1.39	± 1.39	± 0.74	± 0.39

II. To this number have been added the bloodgroups of 309 persons in the towns of Oud-Beyerland and Numansdorp also situated in the Hoeksche Waard (collected resp. by Dr. DE KONING and Dr. FLOHIL).

Number	O	A	B	AB
1591	723	704	124	40
	45.4 %	44.3 %	7.8 %	2.5 %
	± 1.25	± 1.25	± 0.67	± 0.40

In cases where 2 or more sisters or brothers have been tested only the two eldest of these have been taken, the other ones being eliminated from the material.

The blood-index after HIRSZFELD $= \dfrac{A+AB}{B+AB} = 4.5$.

Computed after BERNSTEIN:

$p = 27 \qquad q = 5.5 \qquad r = 67.5 \qquad p+q+r = 100$

For the students (published in the year 1930) we got:

$p = 25.6 \qquad q = 6.8 \qquad r = 67.6 \qquad p+q+r = 100$

For the investigation in the Over Veluwe we got:

$p = 25.8 \qquad q = 5 \qquad r = 68.8 \qquad p+q+r = 99.6$

Dividing the Hoeksche Waard in different parts we get:

III. Puttershoek:

Number	O	A	B	AB
526	234	257	25	10
	44.5 %	48.8 %	4.8 %	1.9 %
	± 2.17	± 2.18	± 0.93	± 0.59

IV. Computing the Hoeksche Waard without Puttershoek:

Number	O	A	B	AB
1065	489	447	99	30
	45.9 %	42.0 %	9.3 %	2.8 %
	± 1.53	± 1.51	± 0.89	±.0.51

V. The eastern parts of the Hoeksche Waard without Puttershoek

(namely the towns of Maasdam, Schenkeldijk, Mookhoek, 's Gravendeel, Strijen, Sas van Strijen) :

Number	*O*	*A*	*B*	*AB*
664	286	301	62	15
	43.1 %	45.3 %	9.3 %	2.3 %
	± 1.92	± 1.93	± 1.13	± 0.58

VI. Taking the town of Oud-Beyerland, situated in the western part of the Hoeksche Waard :

Number	*O*	*A*	*B*	*AB*
217	107	88	15	7
	49.3 %	40.6 %	6.9 %	3.2 %
	± 3.39	± 3.34	± 1.72	± 1.20

VII. The total Hoeksche Waard without Puttershoek and Oud-Beyerland :

Number	*O*	*A*	*B*	*AB*
848	382	359	84	23
	45.0 %	42.3 %	9.9 %	2.7 %
	± 1.71	± 1.30	± 1.02	± 0.56

VIII. Making a separation between the lands poldered before and after the 16th Century :

1. The places Puttershoek, St. Anthoniepolder, Maasdam, Cillaarshoek:

Number	*O*	*A*	*B*	*AB*
723	315	349	46	13
	43.6 %	48.3 %	6.3 %	1.8 %
	± 1.85	± 1.86	± 0.90	± 0.49

2. The towns of 's Gravendeel, Schenkeldijk, Mookhoek, Strijen, Sas van Strijen, Numansdorp, Oud-Beyerland :

Number	*O*	*A*	*B*	*AB*
868	408	355	78	27
	47.0 %	40.9 %	9.0 %	3.1 %
	± 1.70	± 1.67	± 0.97	± 0.59

Considering these percentages (Fig. 1), it can be stated that Puttershoek with its extremely low percentage of bloodgroup *B* is situated in the middle of a territory where this percentage is much higher, reaching a percentage which is very high if compared with the mean one in Holland and resembling the percentage we obtained in the islands of the province of Zeeland [1]). For comparison the columns relating to the 4 bloodgroups of

[1]) To be published in a future paper.

the investigation of the "Over Veluwe" mentioned before and those relating

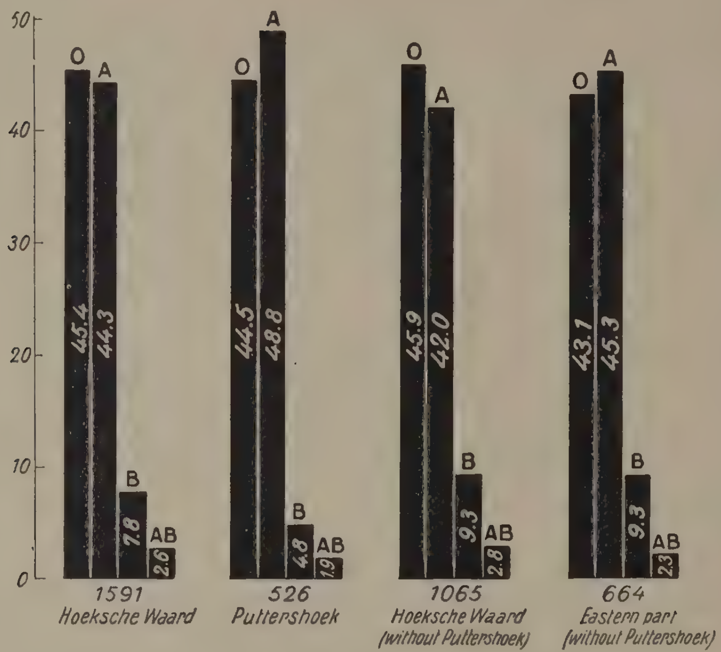

Fig. 1.

to N0. IV of the present investigation have been placed side by side (fig. 2).

If we consider the family names and family relations of those belonging to group *B* and *AB* in Puttershoek it appears that there exist two families who are greatly responsible for the agglutinogenes *B*. Eliminating the persons belonging to bloodgroup *B* or *AB* in these two families there only remain 15 instead of 25 persons belonging to *B* which momentarily can't be traced back to these relationships. This does not mean however that they have not any connections with these families, whose pedigrees could not be traced back any further than the beginning of the 19th century.

So we have to conclude that probably after the St. Elisabethflood in 1421 the settlement of population in this borough has been very poor as to the *B* factor in contrast to the people settling in the surrounding districts.

This low percentage of bloodgroup *B* at Puttershoek is also reflected in the material collected together in the places poldered before the 16th century (VIII 1) when compared with the material from later poldered regions (VIII 2), the larger part of this material having been collected at Puttershoek (526 from the 723 cases mentioned sub VIII 1).

In order to see if any correlation exists in the material collected in the Hoeksche Waard between the bloodgroup and other anthropological traits.

the distribution of the bloodgroups has been compared with the distribution of the colour of the hair and the colour of the eye. The number of head-indices of grown-up people investigated is too small to be taken into account for these correlation studies.

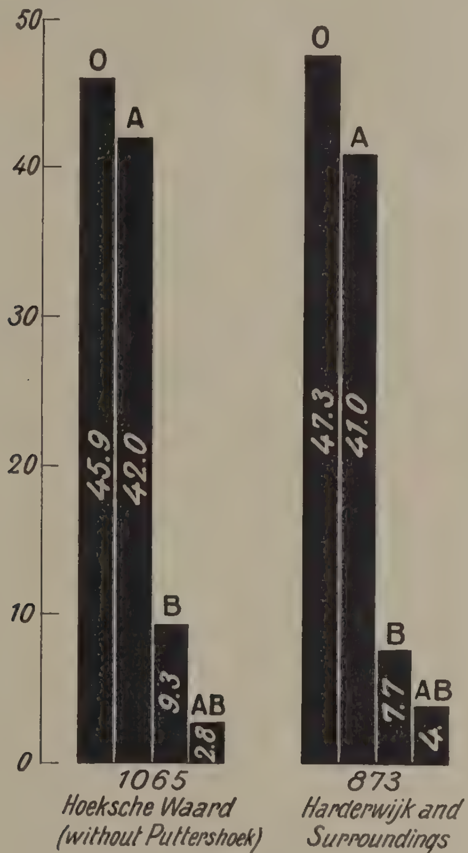

Fig. 2.

The Colour of the Eye.

Among 1267 persons examined in respect to eye colour by the first author 773 or 61.0 procents had light coloured eyes (blue, bluegrey or grey), 494 or 39.0 procent had dark coloured eyes (greybrown, brown or blue (or bluegrey) with brown pigment spots or heterochromic eyes).

Taking all the persons together examined for eye colour in the Hoeksche Waard (1560 persons) these numbers amount to respectively 980 or 62.8 procent ± 1.22 and 580 or 37.2 procent ± 1.22. Table 1 gives the distribution of the different eye colours over the 4 bloodgroups.

It is sufficiently clear from this table that in this material no correlation exists between bloodgroup and eye colour. The same holds true if we consider the material in Puttershoek separately (table 2).

TABLE 1. Bloodgroup and Eye colour in the Hoeksche Waard.

Bloodgroup	Number	Blue, bluegrey, grey eyes	Greybrown, brown, blue (or bluegrey) + brown, or heterochromic eyes
O	710 45.5% ± 1.26	448 = 63.1% ± 1.81 45.7% ± 1.59	262 = 36.9% ± 1.81 45.2% ± 2.66
A	694 44.5% ± 1.26	433 = 62.4% ± 1.84 44.2% ± 1.59	261 = 37.6% ± 1.84 45.0% ± 2.64
B	119 7.6% ± 0.67	75 = 63.0% ± 4.43 7.6% ± 0.85	44 = 37.0% ± 4.43 7.6% ± 1.10
AB	37 2.4% ± 0.39	24 = 64.9% ± 7.85 2.5% ± 0.50	13 = 35.1% ± 7.85 2.2% ± 0.61
Totals	1560	980 = 62.8% ± 1.22	580 = 37.2% ± 1.22

TABLE 2. Bloodgroup and Eye Colour at Puttershoek.

Bloodgroup	Number	Blue, bluegrey, grey eyes	Greybrown, brown, blue (or bluegrey) brown, or heterochromic eyes
O	224 44.0% ± 2.20	137 = 61.2% ± 3.26 48.4% ± 2.98	87 = 38.8% ± 3.26 38.5% ± 3.24
A	253 49.7% ± 2.22	129 = 51.0% ± 3.14 45.6% ± 1.84	124 = 49.0% ± 3.14 54.9% ± 3.30
B	23 4.5% ± 0.92%	13 = 56.5% ± 10.35 4.6% ± 1.25	10 = 43.5% ± 10.35 4.4% ± 1.37
AB	9 1.8% ± 0.54	4 = 44.5% ± 16.55 1.4% ± 0.70	5 = 55.5% ± 16.55 2.2% ± 0.98
Totals	509	283 = 55.6% ± 2.20	226 = 44.4 % ± 2.20

Correlation $O \rightarrow B$ and blue, bluegrey, grey eyes → greybrown, brown eyes = 0.028 ± 0.065
„ $A \rightarrow B$ „ „ „ „ „ → „ „ „ = 0.031 ± 0.060

It is clearly evident from this table that no correlation can be traced.

For the district of Puttershoek 283 persons or 55.6 procent had light coloured eyes (blue, bluegrey, grey) and 226 or 44.4 procent dark coloured eyes (browngrey or brown, blue (or greyblue) with brown pigment spots or heterochromic eyes).

For the districts of the eastern part of the Hoeksche Waard with the exception of Puttershoek (the towns of Maasdam, 's Gravendeel, Schenkeldijk, Mookhoek, Strijen and Sas van Strijen) 403 or 67.6 procent had light coloured eyes, 193 or 32.4 procent dark coloured eyes.

Taking all the persons examined in respect to eye colour in the Hoeksche Waard together excepting those in Puttershoek (1051 persons) 697 or 66.3 procent had light coloured eyes, 354 or 33.7 procent had dark coloured eyes.

The Colour of the Hair.

Among 1259 persons examined by the first author in respect to hair colour, 39 or 31 procent ± 0.49 were red haired, 633 or 50.3 procent ± 1.41 fair, 587 or 46.6 procent ± 1.41 darkblond or black. Taking all the persons together examined for hair colour in the Hoeksche Waard (1556 persons), 42 or 2.7 procent ± 0.41 were red, 741 or 47.6 procent ± 1.27 fair, 773 or 49.7 procent ± 1.27 were darkblond or black haired (table 3).

TABLE 3. Bloodgroup and Hair Colour in the Hoeksche Waard.

Blood-group	Number	Red hair	Fair hair	Darkblond or black hair
O	708 45.5% ± 1.26	9 = 1.3% ± 0.65 21.4% 6.32	349 = 49.3% ± 1.88 47.1% ± 1.83	350 = 49.4% ± 1.88 45.3% ± 1.79
A	692 44.5% ± 1.26	29 = 4.2% ± 0.76 69.0% ± 7.04	316 = 45.7% ± 1.89 42.6% ± 1.82	347 = 50.1% ± 1.90 44.9% ± 1.79
B	119 7.6% ± 0.67	3 = 2.5% ± 1.43 7.1% ± 3.96	66 = 55.5% ± 4.55 8.9% ± 1.05	50 = 42.0% ± 4.53 6.5% ± 0.89
AB	37 2.4% ± 0.39	1 = 2.7% ± 2.66 2.4% ± 2.36	10 = 27.0% ± 7.30 1.4% ± 0.43	26 = 70.3% ± 7.52 3.3% ± 0.64
Totals	1556	42 = 2.7% ± 0.41	741 = 47.6% ± 1.27	773 = 49.7% ± 1.27

The correlation $O \to B$ and fair hair → darkblond or black hair = 0.049 ± 0.035
" " $A \to B$ " " " → " " " " = 0.066 ± 0.023

For the district of Puttershoek of 502 persons examined in respect to hair colour (table 4) 15 or 3.0 procent ± 0.76 were red haired, 160 or 31.9 procent ± 2.08 fair, 327 or 65.1 procent ± 2.13 had darkblond or black hair.

TABLE 4. Bloodgroup and Hair Colour at Puttershoek.

Blood-group	Number	Red Hair	Fair Hair	Darkblond or black hair
O	221 44.5% ± 2.22	4 = 1.7% ± 0.87 26.6% ± 3.61	81 = 35.4% ± 3.22 50.6% ± 3.96	136 = 62.9% ± 3.24 41.6% ± 2.73
A	249 48.8% ± 2.23	9 = 3.5% ± 1.17 60.0% ± 12.7	68 = 26.8% ± 2.81 42.5% ± 3.92	172 = 69.0% ± 2.93 52.6% ± 2.76
B	23 4.8% ± 0.96	2 = 8.7% ± 5.88 13.4% ± 8.8	10 = 43.5% ± 10.4 6.3% ± 1.92	11 = 47.8% ± 10.4 3.4% ± 1.00
AB	9 1.9% ± 0.61	0	1 = 11.1% ± 10.5 0.6% ± 0.61	8 = 88.8% ± 10.5 2.4% ± 0.85
Totals	502	15 = 3.0% ± 0.76	160 = 31.9% ± 2.08	327 = 65.1% ± 2.13

The correlation $O \rightarrow B$ and fair hair → darkblond or black hair = 0.060 ± 0.065
" " $A \rightarrow B$ " " " → " " " " = 0.11 ± 0.061

For the districts of the eastern part of the Hoeksche Waard excepting Puttershoek ('s Gravendeel, Maasdam, Schenkeldijk, Mookhoek, Strijen. Sas van Strijen) from the 596 persons tested for hair colour 18 or 3.0 procent ± 0.70 were red haired, 373 or 62.6 procent ± 1.98 were fair, 205 or 34.4 procent ± 1.95 darkblond or black.

Taking all the persons examined for hair colour in the Hoeksche Waard together excepting Puttershoek (1054 persons) 28 or 2.7 procent ± 0.50 were red haired, 580 or 55.0 procent ± 1.53 fair and 446 or 42.3 procent ± 1.52 darkblond or black.

The Cephalic Index.

Among 496 grown up people tested by the first author as to the index cephalicus 37 or 7.5 procent ± 1.18 were dolichocephalic, 281 or 56.6 procent ± 2.21 mesocephalic and 178 or 35.9 procent ± 2.16 brachycephalic.

From the percentages mentioned it can be stated that on the whole the light eye colour predominates in the different parts of the Hoeksche Waard, especially in the south eastern part (67.6 procent). There is a slight augmentation of dark coloured eyes in Puttershoek (44.4 procent against 32.4 procent in the surrounding districts). As to the colour of the hair a remarkable difference exists between Puttershoek and the other parts of the Hoeksche Waard investigated. No less than 65.1 procent proved to have dark hair against 34.4 procent in the rest of the eastern part and against 42.3 procent of all the persons examined as to hair colour in the Hoeksche Waard except Puttershoek.

However in comparing these percentages of hair colour it should be borne in mind, that in contrast to Puttershoek, in the small towns outside that community, chiefly schoolchildren were examined by the first author. Consequently an augmentation of the hair pigmentation with age has to be taken into consideration.

As to the red hair in the Hoeksche Waard a corresponding high percentage has been found in the above-mentioned investigation in the Over Veluwe (26 on 818 persons examined = 3.2 procent). As to the 3085 students examined a percentage of 2.0 procent red haired have been found.

For each bloodgroup a separation has been made between persons having fair or red hair and light (blue, bluegrey or grey) eyes and those having darkblond or black hair and dark coloured (greybrown or brown) eyes. In table 5 we consider the material of 1282 persons investigated by the first author.

It appears from this table that the first combination is much more frequent in group *O*, *A* and *B* than the second combination. Considering the whole group of 1282 persons, the combination fair or red hair with light coloured eyes is nearly 3 times as frequent as the combination darkblond or black hair with dark coloured eyes.

If however we take Puttershoek separately we find on the contrary that

TABLE 5.

Bloodgroup	Total number investigated	Fair (or red) hair light eyes	Dark hair, dark eyes
O	569	224	111
A	590	141	34
B	97	40	16
AB	26	7	6
	1282	412	167

the combination darkblond or black hair with dark coloured eyes in this material exceeds the combination fair (red) hair with light eyes, as can be seen from the following table:

TABLE 6.

Bloodgroup	Total number investigated	Fair (or red) hair light eyes	Dark hair, dark eyes
O	234	64	60
A	257	50	74
B	25	8	2
AB	10	0	4
	526	112	140

Taking the material collected by the first author with the exception of Puttershoek we get:

TABLE 7.

Bloodgroup	Total number investigated	Fair (or red) hair light eyes	Dark hair, dark eyes
O	489	160	51
A	447	141	34
B	99	32	14
AB	30	7	2
	1065	340	101

For each bloodgroup the combination fair (red) hair with light eyes is here considerably more frequent than the combination darkblond (black) hair with dark eyes. Considering the total numbers the first combination proves to be nearly 3½ times as frequent as the second combination.

These latter tables confirm the fact already stated, that the pigmentation in Puttershoek has been found higher than in the surrounding districts.

In this same paper may be mentioned the selected data (252 cases) collected with the collaboration of some medical students in the districts of Brielle, Oost-Voorne and Hekelingen (Islands of Voorne and Putten).

Number	*O*	*A*	*B*	*AB*
252	105	119	24	14
	41.6 %	43.4 %	9.5 %	5.5 %
	± 3.11	± 3.2	± 1.85	± 1.44

Of 248 of these persons examined in respect to eye colour 132 proved to have blue, bluegrey of grey eyes, 103 greybrown or brown eyes.

From 241 of these persons examined for hair colour 1 proved to have red hair, 120 fair and 120 darkblond or black hair. As to the bloodgroup distribution, in these western parts of the islands as compared with the Hoeksche Waard, no lowering of percentage *B* has been found. This last material collected in the western part is however too small to admit of any conclusion being made. But in a subsequent publication we shall be able to show the same phenomenon, when the western part of the province of Zeeland will be taken into consideration, in which the material dealt with is sufficiently large.

Conclusions.

This second investigation of the settled population in provincial districts leads to the same results as those obtained in the Over Veluwe and

confirms the results from the extensive material taken from Netherland students, namely an absence of significant correlation between bloodgroup and the other anthropological traits investigated. Taking into consideration the probable errors no correlation can be traced.

The percentage of bloodgroup *B* is rather high, if the material is considered without the borough of Puttershoek with its very low percentage of that group (the material investigated at Puttershoek covers more than $^1/_3$ part of the total number of cases). In subsequent publications it will be seen that the percentage of *B* obtained in these islands, with the exception of Puttershoek, is as high as that found in the islands of the province of Zeeland and that this forms a contrast with the lower mean percentage found in many localities of the Netherlands. As stated in our former paper local variations may be considerable even between localities separated by only a few miles, which phenomenon has to be contributed to centuries of intermarriage in our small communities. The findings at Puttershoek give an other good example of this phenomenon which is responsible for the local character of our small population groups, a phenomenon which as we have stated, is reflected in the local distribution of the bloodgroups, but which anthropologically, psychologically and socially, has a much wider meaning. We will reconsider this question when the total Dutch material available has been sufficiently selected, arranged and computed. It is not impossible that in a complete survey of the material some small indications may be gathered that, as to the general bloodgroup distribution in the Netherlands, differences exist which will prove to be of some anthropological significance. There is no reason however at all to expect that a nordic and an alpine race might be traced in our country by means of bloodgroup investigation. This has only be accepted by some other authors in the first enthousiasm about the discovery of these interesting hereditary traits in man. Interesting indeed, if we consider how closely they conform to the law of Mendel without being influenced phaenotypically by any conditions of life or other external conditions.